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An assessment of farm-level input demands and production under risk on rice farms in the Cimanuk River Basin, Jawa Barat, Indonesia

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AN ASSESSMENT OF FARM-LEVEL INPUT DEMANDS AND PRODUCTION UNDER RISK ON RICE FARMS IN THE CIMANUK RIVER BASIN, JAWA BARAT, INDONESIA

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An assessment of farm-level input demands and production under risk on rice farms in the Cimanuk River Basin, Jawa Barat, Indonesia

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I. INTRODUCTION

Policies to promote development strategies are undoubtedly partly guided by policymaker's conceptions of the behavior of the people for whom the policies are directed. In agricultural development, better understanding about farm-level behavior, therefore, should be a crucial factor in formulating decisions that could affect the welfare of farmers.

In the early 1960s, the Government of Indonesia established a program called the BIMAS (Bimbingan Massal = Mass Guidance) following several seasons of successful small localized extension programs. The five essential components of which the program comprised are: (1) fertilizer application, (2) improved seed application, (3) pesticide application, (4) improved water control or irrigation, and (5) better cultivation practices. This was an outgrowth of the "green-revolution" technology that swept most of South and Southeast Asia. Since that time, the program has often been modified and even expanded in response to improvement in the government's ability to coordinate a larger multifaceted program and to accommodate for availability of inputs and the means to distribute them and changes in production technology. But the ultimate goal has always been to increase agricultural production, which in turn, is expected to increase the income of the bulk of the population through crop intensification.

As implementation devices, the government created agencies responsible for: (1) agricultural extension, (2) credit provision, (3) input distribution, and (4) irrigation improvement. Credit was provided by the government through village units organized by Bank Rakyat Indonesia (an assigned public bank). The procedure is that loans are made to individual farmers in the form of vouchers redeemable for seed, fertilizer, and pesticides at a retail outlet in the village area. The presumption is that farmers might be reluctant to use modern inputs because of unavailable cash credit to purchase inputs. By using this procedure, the cash constraint can be alleviated and the adoptions of modern inputs would be enhanced. Despite these efforts, some farmers are still hesitant to take the opportunity, partly due to "unfamiliarity" with the new inputs.

New seed varieties, which are also called high-yielding (HYV) or modern (MV) varieties as opposed to traditional (TV) or local (LV) varieties, are developed in the Agricultural Research Experiment Station through breeding selection and years of local adaptation trial. Due to other intentions of this program, however, these seeds are developed in a very controlled environment which requires adequate fertilizer, pesticides, and water applications and better cultivation practices that are not generally available on a farmer's plot.

These technologies which are often also called "seed-fertilizer" technologies are undisputably responsible for a tremendous increase in aggregate agricultural production. Average national yields also have increased (Table 1). Even when evaluated in the farmer's field in 1970-71, the new technologies demonstrated potential (Widodo et al., 1979). Yet, the average national yield and the potential yield in the farmer's field do not approach the levels obtained in experiments conducted on

Table 1. Rice production and intensification program in Indonesia, 1964-1978[a]

Year	Harvested area (thousand ha)			Yield[b] (t/ha)			
	Intensification	Non-intensification	Total	Intensification	Non-intensification	Aggregate	Total production (thousand t)
1964	.1	6,980	6,980	3.69	1.21	1.21	8,420
1965	10	7,318	7,328	2.57	1.21	1.22	8,877
1966	340	7,351	7,691	2.55	1.15	1.21	9,339
1967	522	6,994	7,516	2.28	1.12	1.20	9,047
1968	1,597	6,423	8,020	1.51	1.39	1.45	11,667
1969	2,130	5,884	8,014	1.89	1.40	1.53	12,249
1970	2,153	5,982	8,135	2.18	1.41	1.62	13,140
1971	2,788	5,537	8,325	2.05	1.45	1.65	13,724
1972	3,160	4,729	7,898	2.26	1.27	1.67	13,183
1973	3,988	4,415	8,403	2.20	1.32	1.74	14,607
1974	3,723	4,786	8,506	2.27	1.42	1.80	15,276
1975	3,637	4,858	8,495	2.22	1.43	1.80	15,185
1976	3,614	4,754	8,368	2.38	1.52	1.90	15,845
1977	4,249	4,111	8,360	2.27	1.52	1.88	15,876
1978	4,834	4,059	8,893	2.34	1.55	1.98	17,598

[a]Cited by Herdt and Capule (1983).

[b]Milled rice.

research stations. Worse yet, even in the irrigated areas farms' yields are well below the yield potential (Barker, 1979).

A. Statement of the Problem

Knowing that increased rice production or farmer's income is still a major goal of the Government of Indonesia and realizing that there is a large gap between farmer's yields and potential yields under most conditions in experiment stations, empirical investigations have to be undertaken to identify and quantify major constraints affecting input applications as well as economic and technical performance at the farm level.

Recently, a number of studies have been able to define the gap. They also have attempted to identify factors affecting the gap. Herdt and Wickham (1975) defined the gap as the difference between the yield potential at the experiment station during the dry season in a good year and the average national level. They found that approximately 40 percent of the yield gap was estimated to be the result of socioeconomic factors classified as economic constraints, lack of available inputs, and nonadoption of technology.

In a different setting, Gomez et al. (1979) conceptualized the gap as exhibited in Figure 1. The model breaks the difference between the actual farm yield and the experiment station yield (the yield gap) into two distinct parts by introducing an intermediate yield level representing the potential farm yield or yield obtained in farmers' fields using modern technology. The first part, yield gap 1, is the difference between experiment station yield and potential farm yield.

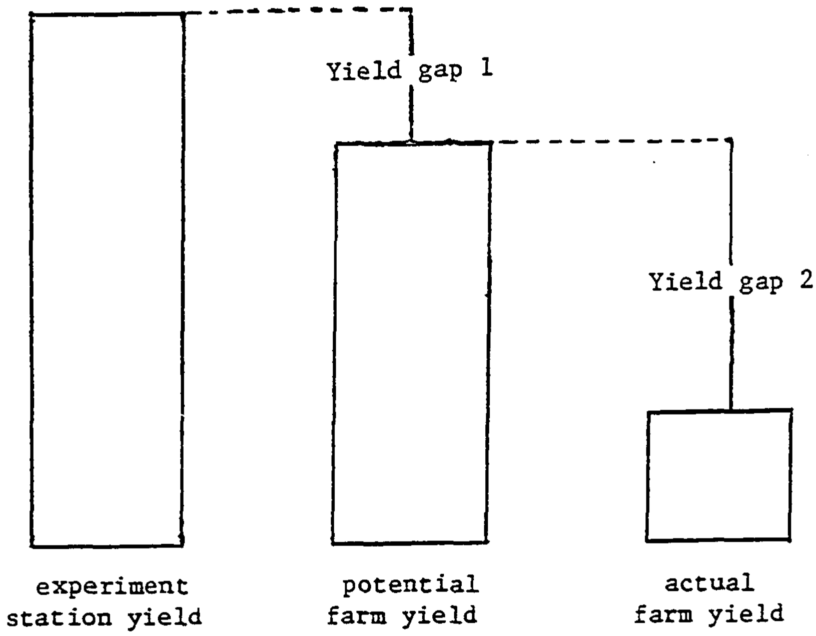

Figure 1. The concept of yield gaps between an experiment station yield, potential farm yield, and actual farm yield

It is due to environmental differences between experiment stations and the actual rice farms. There may also be some components of the technology that are not transferable from the experiment station to the farmers' fields. The second, yield gap 2, is the difference between the potential farm yield and the actual farm yield. This could be assumed to be made up of two constraints, that is, biological and socioeconomic constraints.

Generalizing, we could say that the determinants of "seed-fertilizer" adoption could be grouped into three categories: (1)

technological and physical factors, (2) economic factors, and (3) institutional factors. The question, however, still lingers: (1) Why are some farmers still reluctant to adopt modern technologies while many others have adopted?, (2) Why are many farmers unable to achieve the full potential yields of the new technology?

One possible explanation could be the lack of information and imperfect knowledge about modern technologies on the part of the farmers. Hence, a complete analytical framework for investigating adoption behavior at the farm level should be of interest since farm-level observations reduce potential problems with aggregation bias and because the effects of farmer socioeconomic variables can be examined. This is the first subject focused on in this research.

Another important aspect that should not be neglected in analyzing the agricultural production process is the risk factor. Farmers are faced with many risky and uncertain prospects when making decisions on the allocation of their resources. They are clearly confronted with: (1) price (in both input and output) uncertainty, (2) technology or production uncertainty, (3) weather variability and other physical or biological hazards like pests and diseases, (4) institutional arrangements uncertainty, and (5) government policies and control. One specific issue that needs to be addressed in research is the evaluation of the marginal effect or elasticities of new inputs on the variability of output and the estimation of optimal input demands under the assumption of production risk. The degree of risk associated with new inputs may have been a major problem in their adoption in Indonesia.

Variability of input supplies such as seeds, fertilizer, and pesticides contribute to a high variability in yields per hectare, and therefore, to the farmers' income. For example, HYVs are believed to be more demanding of adequate moisture at the right time and more susceptible to pests and diseases. It might be appropriate, therefore, to hypothesize that the farmers production decisions are influenced by their attitude toward risk and uncertainty. Yet, this issue has never been explored in the context of Indonesian agriculture. Most studies in the area have always implicitly assumed the neoclassical profit maximization without risk consideration. This hypothesis is applied to data available from three-year (six seasons) observations of output and input use by representative rice farmers in the Cimanuk River Basin, Jawa Barat, Indonesia.[1]

B. The Research Objectives

1. To develop a model of the adoption decision for new agricultural innovations emphasizing the role of economic factors reflected by the potential difference between the associated costs of new technology and that of old technology. In addition, to estimate elasticities of demand for inputs in this model, allowing seed choice adjustment in line with the induced-innovation hypothesis in part of farm producers. Inability to recognize this selection model will overestimate those elasticities derived from the seed-unadjusted model.
2. To develop a model incorporating risk in the production process. Then, to evaluate the effect of input use upon the

variability of output.

3. To test the hypothesis that risk may be important in the decision-making process among farmers. Specifically, optimal implied input demands under the production risk model would be contrasted with that of risk-neutral model.

4. To examine the existence and the extent of risk aversion of rice farmers.

The dissertation is organized as follows. Chapter II provides a brief background of Indonesian economy and agriculture sector. In Chapter III, review of the literature on the subjects in question will be presented. Section A of the chapter focuses on the model of adoption of new technological innovations in agriculture. The empirical application of this model is also discussed. In Section B, the theory of decision making under risk and uncertainty is introduced, along with empirical studies in agriculture.

Chapter IV treats the empirical estimation methods. Study area, data and variables and their descriptions are presented.

Chapter V considers empirical results and discussion of the adoption behavior model in Section A, and of the production risk in its second section.

Finally, Chapter VI presents the summary of the results, conclusions, and implications for further research.

NOTES TO CHAPTER I

[1]Sampling procedures and variables used are elaborated further in Section C of Chapter IV. Admittedly, the time component of the data is extremely limited, so is cross-section farm-level data in general. These are the only data available that have ever been documented on particular individual farms covering more than a year.

II. A SETTING IN INDONESIAN AGRICULTURE

Observation of the Indonesian economy in a wider perspective in terms of activities and time has its own merit. However, circumstances that emerged in the mid-sixties in the political system and its influence on the general economy and on agriculture call for a brief review which is presented in this section. The deep involvement of the government at that time is undoubtedly responsible for shaping the course of the economic activities, and that involvement is still prevalent today. In many respects, the type and complexity of the problems today are becoming obvious. As in many developing countries, the government is a dominant force in the economy.

A. Role of Agriculture

As is typical in less developing countries, agriculture is still the leading sector of the economy. Even in the early eighties, the agriculture sector accounts for at least 60 percent of Indonesia's total labor force (and very much more than this if the work undertaken by wives and families of the peasant farmers is taken into account). Clearly, agriculture is a major source of income for the bulk of the population. Another contribution of agriculture is in the earnings of balance of payments (Table 2). From the table, the value of agriculture exports declined until 1976 and rose again in 1977 until 1979 but in 1980 dropped back down forward. On the other hand, crude minerals' value increased until 1976 and dropped somewhat until 1979 but rose up again from then onward. In terms of contribution to gross domestic

Table 2. Composition of merchandise trade 1973-1982 (as percentage of total value) (Source: Yearbook of International Trade Statistics, United Nations (Miscellaneous issues))

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Exports										
Agricultural products	38.8	20.9	15.5	21.3	23.6	22.4	23.8	18.4	10.9	8.4
Crude minerals	44.5	64.2	71.3	67.6	64.9	65.8	61.2	67.6	75.3	80.3
Manufacture goods	16.7	14.9	12.2	11.1	11.5	11.8	14.9	14.0	13.8	11.3
Total exports	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exports value (in billion US dollars)	3.2	7.4	7.1	8.6	10.9	11.6	15.6	21.9	22.3	22.3
Imports										
Food and beverages	10.1	14.5	12.2	14.1	16.0	17.1	15.3	11.9	10.1	6.4
Other consumer goods	4.7	3.8	2.8	3.7	3.8	4.0	3.2	3.0	2.8	2.2
Fuels	1.3	4.0	4.7	7.4	11.4	8.4	10.7	15.7	12.8	4.0
Other raw materials	42.6	42.2	43.4	34.4	33.2	34.6	38.7	36.1	38.2	32.3
Transport equipment	13.7	12.1	13.0	10.8	10.7	13.7	9.5	11.6	12.4	11.4
Other capital goods	27.6	23.3	24.0	29.2	24.8	21.9	22.1	21.4	23.2	26.4
Total imports	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Imports value (in billion US dollars)	2.3	3.9	4.8	5.7	6.2	6.7	7.2	10.8	13.2	16.9

product (GDP), the share of agriculture in the economy has declined since the mid-sixties (Table 3). In constant prices, agriculture (food and cash crops, forestry, and fishery) accounted for 54 percent of GDP in 1960, dropped down to 44 percent in 1971, and just over 31 percent in 1980. This trend was more obvious from current market prices where agriculture's share of GDP in 1980 was less than 26 percent. These figures can lend themselves to showing the structure of agricultural economy.

Based on the Agricultural Census undertaken in 1973, it was documented that there were 14,373,542 agricultural enterprise units which can be assumed as farm households, and recent Population Census of 1980 data revealed that there were 17,468,560 farm households which made up 57.7 percent of total Indonesian households. Number of farmers has consistently increased but the majority of them were categorized as landless farmers. This situation resulted from peasant small holdings which over generations become progressively smaller and smaller as each generation's holding is divided up among the heirs (Table 4).

Consequently, there are two distinctive types of easily recognizable farming systems, namely, small holding private farms (or peasant farms) and cash crop estates. The first type generally produces basic food crops and most of them are on basic subsistence levels as opposed to the second which typically produces non-food crops being exported into the international market. In spite of this, owner-operated smallholder farms also dominate in the estate crop subsector where half of its production came from smallholder farms. Most

Table 3. Structure of Gross Domestic Product (GDP), selected years, 1960-80 (as percentage of GDP)

	1960	1967	1971	1980[a]
Current Prices				
Agriculture, Forestry, and Fishing				
Farm food crops	34.3	35.5	26.2	14.5
Farm nonfood crops	7.2	5.4	5.3	3.1
Estate crops	3.3	2.2	2.9	1.5
Livestock products	4.8	3.9	3.4	2.3
Forestry	2.3	0.7	3.9	2.5
Fishing	1.9	6.4	3.2	1.8
Total Agriculture, Forestry and Fishing	53.8	54.1	44.9	25.7
Mining	3.7	2.7	8.0	26.7
Manufacturing	8.5	7.3	8.4	8.8
Utilities	0.3	0.3	0.5	0.5
Construction	2.0	1.7	3.5	5.7
Commerce	14.3	17.6	16.1	14.0
Transportation	3.7	2.2	4.4	3.9
Financial services	1.0	0.5	1.2	2.4
Public administration and defense	4.5	4.8	5.8	7.2
Other services[b]	8.2	8.8	7.2	5.0
Total GDP	100.0	100.0	100.0	100.0[c]
(In billions of rupiahs)[d]	(0.39)	(848)	(3,672)	(43,765)
Private consumption	79.7	92.7	77.1	57.2
Government consumption[e]	11.5	7.4	9.3	12.7
Gross investment	7.9	8.0	15.8	21.7

[a]Preliminary.

[b]Including ownership of dwellings.

[c]Figures do not add to total because of rounding

[d]For value of the rupiah: from 1978 to 1983 was Rp 625/US dollar, and from 1983 to present is Rp 970/US dollar.

[e]Excluding state enterprises.

Table 3. (continued)

	1960	1967	1971	1980[a]
Net exports	-0.8	-8.1	-2.2	8.4
Net factor payments[f]	-0.8	-1.1	-1.8	-5.0
Constant Prices[g]				
Agriculture, forestry, and fishing	n.a.[h]	51.8	44.0	31.4
Mining	n.a.	3.8	9.9	9.5
Manufacturing	n.a.	8.3	8.8	14.3
Utilities	n.a.	0.4	0.4	0.7
Construction	n.a.	1.6	3.0	5.7
Transportation and communications	n.a.	3.6	3.8	5.4
Other services[b]	n.a.	30.5	30.1	33.0
Total GDP	n.a.	100.0	100.0	100.0[c]
(In billions of rupiahs)[d]	n.a.	(0.45)	(5,545)	(10,954)
Private consumption	n.a.	85.3	72.1	75.7
Government consumption[g]	n.a.	8.0	9.4	15.2
Gross investment	n.a.	7.4	15.6	26.2
Net exports	n.a.	-0.7	2.9	-17.1

[f]Payment of wages, profits, and interest to foreign individuals and firms.

[g]1967 data in 1960 prices; 1971 and 1980 data in 1973 prices.

[h]Not available.

Table 4. Number of households according to hectareage land operated (Source: B.P.S. (1982))

Land hectareage and status	1973 Agricultural Census		1980 Population Census	
	Number	Percent	Number	Percent
Less than 0.5 ha	6,560,758	45.7	11,027,653	63.3
Owned operated	4,907,495	34.2	7,914,305	45.3
Owned and rented	1,356,843	9.4	1,018,048	5.8
Rented	296,420	2.1	2,095,300	12.0
More than 0.5 ha	7,812,784	54.3	6,440,907	36.9
Owned operated	5,839,027	40.6	4,935,162	28.3
Owned and rented	1,813,831	12.6	999,254	5.7
Rented	159,926	1.1	506,491	2.9
Total	14,373,542	100.0	17,468,560	100.0

agricultural estates, however, were owned and operated by government enterprises, but some were in private hands. One other type of farming is shifting cultivation but is small in terms of hectareage and number of farmers involved. Another system that is becoming more distinguishable in recent years due to capital influx from abroad is natural resource exploration (beyond oil and gas) such as deep water fishery and forest product exploitation. Needless to say, the latter system does not involve many farmers. The above picture is becoming more gloomy due to unbalanced concentration of population. Sixty percent of the Indonesian population reside in Jawa, 19 percent in Sumatera, seven percent in Sulawesi, five percent in Kalimantan, and the rest in other parts of the country. Approximately 11 million hectares of smallholdings were devoted to the production of food crops but they average less than one hectare in size--barely half a hectare in Jawa. Consulting further the official 1980 census data, the number of landless farm households increased approaching three to four millions in 1980. On Jawa alone, official estimates in 1980 placed 30 percent of farms households in the landless category, and other estimates ran to more than 50 percent. As shown in Table 5, peasant farmers (less than 0.5 ha holding) are about 73 percent in Jawa and 63 percent nationally.

B. Government Agricultural Policy

Right from the beginning of the New Order government established in the mid-sixties, it was recognized that the agricultural sector was very vital to the economy. This importance is reflected in a series of five-year economic development plannings (REPELITA) mapped out by BAPPENAS

Table 5. Number of peasant farm households compared with total farm households (from 1980 Population Census) (Source: Departemen Pertanian, 1983)

Islands	Below 0.25 ha (1)	0.25 to 0.50 ha (2)	[(1)+(2)] (3)	Above 0.50 ha (4)	[(3)+(4)] (5)	[(3)÷(5)] (6)
Jawa	4,433,057	3,098,265	7,531,322	2,830,057	10,361,379	72.68%
Sumatera	837,891	933,408	1,831,299	1,738,057	3,569,524	51.30%
Kalimantan	128,724	191,446	320,170	491.474	811 644	39.44%
Sulawesi	247,837	366,062	613,899	709,469	1,323,368	46.38%
Bali	66,614	104,288	170,902	146,816	317,696	53.79%
NTB and NTT	165,892	235,346	401,238	382,458	783,696	51.19%
Maluku and Irian Jaya	84,339	74,484	158,823	142,408	301,231	52.72%
Indonesia	5,964,354	5,063,299	11,027,653	6,440,907	17,468,560	63.12%

and projected into the 1990s. Looking at the specific theme of each plan; the first of the series, REPELITA I (1969-1974) was to emphasize the development of basic agriculture; REPELITA II (1974-1979), balancing agricultural production; REPELITA III (1979-1984) concentration on industries supporting agriculture; REPELITA IV (1984-1989) developing basic industry: REPELITA V (1989-1994) launching defense and security industries; and REPELITA VI (1994-1999) stressing on balanced and self-sustaining production in all sectors. Nonetheless, these plans should not be conceived to imply that the agricultural sector is an isolated activity from the rest of the economy. In fact, many of the attempts to stimulate development in agriculture by improving the physical, technical, and institutional supports for production rely upon the progress being achieved in other sectors.

Land development schemes have taken the form of public works to expand and improve irrigation systems and to the opening up of new lands on the Outer Islands (islands other than Jawa). Another systematic complementary way of developing the land outside of Jawa for agriculture, so it was and still is perceived, has been the transmigration program of moving and settling people from Jawa to the Outer Islands. Moreover, there are some other technical programs ranging from the provision and development of modern agricultural inputs to extension services leading to wide-spread adoption of "green-revolution" technology, particularly in the cultivation of food crops, such as rice, as has been outlined previously. These technical programs are: first, a local representative of the BRI responsible for managing the bulk of the BIMAS program which involved credit from this rural banking facility; second, a farm cooperative responsible for distributing seed, fertilizer, pesticide, and equipment needed for the members of the programs[1]; third, BULOG as one of the most powerful economic institutions in the country responsible for procuring enough rice for the government to keep its price to a target level set by a special coordinating committee[2]; fourth, an agricultural extension assigned to organized groupings of farmers consisting of extension field workers, farm leaders, and farmers in order to enhance ideas exchanged among them; fifth, an agricultural research which is vital to the extension effort and carried out at research institutes and centers around the country.

To the extent of financial commitment, development spending has taken an increasingly large share of the national budget. Under REPELITA I and REPELITA II, government investment went toward developing a basic infrastructure of transportation, communication, and power generation and toward strengthening agricultural production by expansion of irrigation projects and the provision of fertilizer as explained before (Table 6). Furthermore, from the table it can be observed that under REPELITA III, the emphasis has shifted slightly to investment in industry and education, health, housing, and water facilities.

C. Importance of Paddy Production

Paddy or rice is a major staple food of the Indonesian population. Consideration of the Indonesian diet emphasizes the dominance of rice consumption in the republic. The poorest 30 percent of the population

Table 6. Development expenditures, selected periods, fiscal years (FY) 1969-82 (as percentage of total development expenditures)

Sector	Repelita I[a] FY 1969-73	Repelita II[a] FY 1974-78	Repelita III, FY 1979-83[a]			
			FY 1979	FY 1980	FY 1981[b]	FY 1982[b]
Agriculture						
General	17.0	12.6	9.5	11.2	9.7	14.5
Fertilizer	2.7	6.7	3.2	4.5	5.0	n.a.[c]
Total agriculture	19.7	19.3	12.7	15.7	14.7	14.5
Industry and Mining	7.0	8.0	10.0	8.5	8.2	15.2
Electric Power	8.8	10.1	8.2	7.1	7.7	n.a.
Transportation, Communication, and Tourism	21.1	17.8	11.6	13.2	12.7	12.8
Manpower and Transmigration	n.a.	2.1	4.0	5.5	6.8	7.0
Regional Development	17.0	11.1	8.4	8.1	9.6	8.6
Education	6.1	8.3	9.0	9.7	12.3	15.1
Health	2.8	2.8	3.5	3.7	4.0	3.7
Housing and Water	n.a.	2.1	2.9	3.2	2.4	3.3

Government Services	5.6	6.4	11.8	11.8	11.5	10.1
Investment through State Banks	9.1	9.0	11.6	6.6	3.1	3.1
Other	2.8	3.0	6.3	6.8	7.0	6.6
Total[d]	100.0	100.0	100.0	100.0	100.0	100.0

[a]Repelita means Five-Year Development Plan.

[b]Draft budget.

[c]Not available.

[d]Figures do not add to total because of rounding.

spend 37 percent of their budget on rice as recorded by the 1976 SUSENAS survey (Socio Economic Survey). Timmer (1975) also observed that not only did rice expenditure use up to 31 percent of living expenses in Jakarta, but was also rice used as the primary wage good of the economy. The direct consequence is that it is one of cost push inflation factors. Beyond that, rice seems to have a psychological role in determining anticipated inflation which in turn is considered as a price leader by Indonesian economists (Dapice, 1980; Mears, 1981).

Consulting from Table 7, apparent consumption per capita in column 6 has increased steadily. Although production has also increased making Indonesia the world's fifth largest rice producer, ironically at the same time it has been the world's biggest rice importer accounting for up to 30 percent of total world imports. Much of Indonesia's revenue, mostly from petroleum export, earned during the eighties has dissipated in the need to import substantial amounts of rice leveling at 2.5 million metric ton or more per year from countries such as Thailand, Taiwan, and the U.S.A. The situation has been made worse by the steady improvement in Indonesia living standards, which translates into an increase in rice consumption by 4 percent per year in addition to the 2 percent per year average growth in population.

Therefore, there are apparently two seemingly antagonistic objectives being pursued simultaneously by the government, namely, economic stabilization on one hand and self-sufficiency in food and increased production on the other. The presumption was that rice price is not only a part of the economic stabilization, but also a means to

Table 7. Average annual per capita available and apparent consumption of milled rice in Indonesia, 1954-1983 (in millions of metric ton) (Sources: Production (converted from paddy at 68%) and population data from the Central Bureau of Statistics; import and stock changes from Bulog. Mears (1984))

Calendar year	Production	Imports	Effect of Bulog's stock changes[a]	Self-sufficiency[a] surplus (+) or deficit (-)	Apparent consumption kg/per capita/ per year
1954	7.84	0.26	-0.09	-0.17	88
1955	7.51	0.13	+0.40	-0.53	87
1956	7.60	0.82	-0.06	-0.86	89
1957	7.63	0.55	+0.06	-0.61	85
1958	7.98	0.92	-0.06	-0.98	90
1959	8.29	0.89	+0.02	-0.91	91
1960	10.17	0.89	+0.08	-0.97	109
1961	9.58	1.06	+0.03	-1.09	101
1962	10.28	1.02	+0.02	-1.04	106
1963	9.16	1.04	-0.12	-0.96	92
1964	9.61	1.01	0.00	-1.01	96
1965	10.24	0.20	+0.10	-0.30	92
1966	10.75	0.31	-0.10	-0.21	94
1967	10.40	0.35	+0.03	-0.38	91
1968	11.67	0.63	-0.35	-0.28	98
1969	12.25	0.60	+0.25	-0.83	104
1970	13.14	0.96	-0.27	-0.69	107
1971	13.72	0.50	0.00	-0.49	107
1972	13.18	0.75	+0.33	-1.08	106
1973	14.61	1.64	-0.41	-1.23	114
1974	15.28	1.06	-0.27	-0.79	113
1975	15.18	0.67	+0.22	-0.89	110
1976	15.84	1.29	+0.08	-1.37	116
1977	15.88	1.99	+0.03	-2.02	118
1978	17.52	1.83	-0.67	-1.16	120
1979	17.87	1.91	+0.29	-2.20	126

[a]Allows for changes in Bulog's stocks but not those in the private sector, as country-wide or other surveys of private sector stocks have not been made. Also assumes 10% losses during harvesting and for seed plus 1% loss in marketing. This is an increase in losses from earlier calculations.

Table 7. (continued)

Calendar year	Production	Imports	Effect of Bulog's stock changes[a]	Self-sufficiency[a] surplus (+) or deficit (-)	Apparent consumption kg/per capita/ per year
1980	20.16	2.00	-0.88	-1.12	130
1981	22.29	0.48	-0.55	+0.07	132
1982[b]	23.19	0.30	+0.46	-0.76	140
1983[b]	23.97	1.16	+0.49	-1.65	146

[b]Preliminary.

achieve consumer price stabilization. To achieve these objectives, two options are available, that is, production incentives and consumption disincentives using either pricing policy or import levies or quotas on one hand and to increase physical production through input subsidies, government investment in irrigation, land reclamation, and basic agricultural education on the other. Either way, both measures indispensably require substantial amounts of funds which means an excessive financial burden for the government to bear. Apparently, the second approach has always been the popular instrument for the last 20 years. The consequence is that food policy which was practically assumed as rice policy has always been in favor of consumers (Mubyarto, 1970). This assertion has also been shown still in existence even in the early eighties by the work of Afiff et al. (1980), Dapice (1980), Mears (1981), Teken and Suwardi (1982) who used applied welfare economic analysis. This situation prompted the interesting question: "Which alternative would have been financially less burdensome to the government and to the society?" This has been addressed by two studies (Rasahan, 1983; Sastrohoetomo, 1984). Rasahan found that due to the deep government involvement in rice policy, Indonesian rice consumer price has been subsidized in relation to world price on average by 20 percent in the last decade. This amounts to theoretically implying that there exists an equitably tax imposed on domestic rice production. The latter study suggested if any form of subsidies would have been eliminated letting rice and fertilizer prices fluctuate based on the market mechanism, the benefits would have outweighed the cost generated under the situation.

The sole responsible institution to materialize and regulate the food policy in general and rice policy in particular is BULOG, which does so by being authorized to keep the price at target level by releasing its stock during shortage season and absorbing excess supply during harvest season nation-wide. Originally, BULOG was mainly concerned with rice procurement but recently its role has been expanded to include other basic food necessities such as sugar, corn, kerosene oil, cooking oil, soybean, and salted fish procurement.

NOTES TO CHAPTER II

[1]In the area where cooperatives had not yet been established, private traders were allowed to handle these inputs.

[2]This committee meets the president on a regular basis to discuss market performance of food products.

III. REVIEW OF LITERATURE

This chapter provides an overview of existing literature on the subjects related to the approaches of this research. In Section A, models and empirical studies of adoption of new innovations are considered. The section discusses some attempts to explain what variables could influence farmers in adopting new agricultural innovations. Section B treats the theory of decision making under risk and uncertainty. It first summarizes risk modeling and then describes some empirical strategies for measuring risk or eliciting expectations. The literature on the risk subject is quite diverse, ranging from normative to positive studies, from descriptive to prescriptive studies, and from subjective to objective studies. These distinctions will not be attempted in this review.

A. Adoption of New Agricultural Innovations

Since the 1960s, we have witnessed the introduction of new technologies, especially in wheat and rice farms in developing countries. These technologies which are interchangeably called "seed-fertilizer" or "green-revolution" technologies are unquestionably responsible for a tremendous increase in aggregate agricultural production in those areas. Yet, several studies have concluded that the ensuing benefits have not been equitably shared among producers and that the programs have only partially successful.

Anden-Lacsina and Barker (1978) claim that despite the advance generated by the development of rice varieties with more resistance to insects and diseases and with improved quality (taste and appearance) helping to extend the area where the HYVs are grown, the new rice varieties had spread to only about a quarter of the rice-growing area in Asia by the early 1970s. Measured by observed rates of adoption, the picture is also similar.

Having been able to identify constraints to rapid adoption innovations such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, inefficient human capital, absence of equipment to relieve labor shortages, chaotic supply of complementary inputs (such as seed, chemicals, and water), and inappropriate transportation infrastructure (Feder et al., 1985), many development projects have attempted to remove some of these constraints by introducing facilities to provide credit, information, the orderly supply of necessary and complementary inputs, infrastructure investments, and marketing networks. The removal of these constraints was expected to result not only in the adoption of improved practices but also in a change in crop composition, which was then expected to increase average farm incomes even further. Nevertheless, expectations have been only partially realized.

Subsequent studies which attempted to explain the pattern of adoption behavior have been reported in the literature both theoretically and empirically. While not all the literature on the topics can be reviewed here, some of the works will be mentioned. (For a very extensive survey that is recently reported, see Feder et al.

(1985)).

Most of the theoretical studies of adoption behavior of individual farmers use static analysis that relates the degree of adoption to the factors affecting it. For instance, the problem may be characterized as a farmer who has to choose between two technologies: the traditional technology and a modern technology such as the use of HYVs and the inputs associated with them (fertilizer, irrigation, and pesticides) with or without some form of fixed capital goods. Models following this approach investigate how much is allocated to modern technology and what the input-land ratios of modern inputs are under different circumstances [Hiebert (1974), Nelson and Phelps (1966), Welch (1970), Feder (1980), Just and Zilberman (1983), Pyle and Turnovsky (1971), Roumasset (1976), Bell (1972), Zilberman and Just (1984)].

A dynamic model is constructed from the static model using theoretical or heuristic arguments regarding the behavior over time of the farmer's perception of production-function and price-distribution parameters. For instance, Hiebert argues that the farmer learns his perceived distribution of technical parameters shifts over time from a lower payoff to a higher payoff. This induces farmers to increase their use of new technology. Likewise, in models that incorporate a credit constraint, one can assume that, over time, cash availability to farmers is increased by the increased profits from partial adoption. Belonging to this category are the works by O'Mara (1971), Lindner et al. (1979), Lindner (1980), Stoneman (1981), Lindner and Fischer (1981).

Based on the key explanatory factors affecting adoption, the empirical literature can be summarized as follows:

1. **Farm size:** This is one of the first factors on which the empirical adoption literature is focused. However, it varies according to the characteristics of technology and institutional setting. Particularly, the relationship of farm size to adoption depends on such factors as fixed adoption costs, risk preferences, human capital, credit constraints, labor requirements, tenure arrangements and so on. The importance of this variable has been demonstrated by the studies of Binswanger (1978), Dobbs and Foster (1972), Gafsi and Roe (1979), Weil (1970). Many other empirical studies also suggest that the use of HYVs and some modern variable inputs initially tends to lag behind on smaller farms. For example, see the studies by Parthasarathy and Prasad (1978), Perrin and Winkelmann (1976), and Jamison and Lau (1982). With respect to the intensity of fertilizer and pesticide use per unit of land, a more confusing pattern of behavior prevails. While many studies indicate no significant difference in chemical input use per acre between farms of different size [see Lipton (1978), Parthasarathy and Prasad (1978), Burke (1979), Singh (1979), and Kalirajan (1981)], others indicate a positive relationship between the amount of fertilizer applied per hectare of fertilized land and farm size as shown by Perrin and Winkelmann (1976), Clawson (1978), and in a number of other studies cited by Singh (1979). On the other hand, some empirical studies found negative relationships between intensity of use of modern inputs and farm size as reported by van der Veen (1975) and Srinivasan (1972).

2. **Risk and uncertainty:** In most cases, innovations induce a

subjective risk (that yield is more uncertain with an unfamiliar technique) and quite often objective risks also (due to weather variation, susceptibility to pests and diseases of new seeds, uncertainty regarding timely availability of important inputs). For instance, Dalrymple (1978) acknowledges that HYVs' techniques require a well-irrigated supply of water and thus the attainment of the full potential of the HYVs without undue risk requires an assured water supply. Similarly, Schutjer and van der Veen (1977), Schluter (1974), Wolgin (1975), and Moscardi and de Janvry (1977) conclude from their survey that the adoption of new agricultural technology may require the adopter to accept a greater degree of risk and uncertainty. However, empirical studies have very rarely treated this factor, because it is difficult to measure. One example of such an attempt is O'Mara's (1980) study through direct interviews elicitating the farmer's subjective yield distributions and Binswanger's et al. (1980) study through gambling experiments. Another example is Herath et al. (1982) who compare three alternative decision models to explain farmers' actual behavior. From a different angle, a Gafsi and Roe (1979) study supposes that farmers' technology choices are based on their objective probabilities and hence on their exposure to information regarding new technology. A possible hypothesis that will be a subject to be tested is that more exposure to appropriate information through various communication channels (such as radio, television, newspapers, extension workers, group leaders) reduces subjective uncertainty.

While these studies are motivated by the conceptual work of Rogers

(1957, 1962) on stages of experimentation, few of them (e.g., O'Mara, 1980) apply the more sophisticated Bayesian models of learning such as the one proposed by Lindner (1980).

3. **Human capital:** This notion was inspired by Schultz (1964) who argues that frequent introduction of new-technologies results in disequilibrium suboptimal use of inputs and technologies even though, in traditional agriculture, resource allocation is efficient. Welch (1978) extended and applied this concept suggesting that the contribution by the human factor to the returns from agricultural production can be attributed to two abilities, that is, worker ability and allocative ability. He adds that both abilities improve as experience and health improve. Formal schooling is hypothesized to play a much more important role in determining allocative ability than worker ability. This hypothesis has been supported by several studies on dynamic environment as shown by Welch (1970), Petzel (1976), Petzel (1978), Huffman (1977), Rosenzweig (1978), Jamison and Lau (1982), and Wozniak (1984). However, in less developed countries the results are mixed. Ram (1976), Sidhu (1976), and Pudasani (1983) have also demonstrated the effect of education but Mangahas (1970) concludes that schooling (formal education) has little effect on the probability of Philippines' farmers adopting a number of modern agricultural practices. This conclusion is also demonstrated by Kalirajan and Shand (1985) in India who suggested rather the importance of non-formal education.

4. **Availability of information:** This is related to the human capital factor and is thought to be necessary to make innovative

decisions. This information might come in a form of exposure to extension service, from mass media and so on. This has been shown by the works of Gafsi and Roe (1979), Lockheed et al. (1980), Kalirajan and Shand (1985). Feder and Slade (1984) have also modeled a decision involving new technology by incorporating the decision to acquire information.

5. **Labor availability:** New agriculture technologies are not similar in their respect to labor. Some are relatively labor-saving and others are labor-using. Moreover, new technologies may increase the seasonal demand of labor so that adoption may be less attractive for those with limited family labor or those operating in areas with less access to labor markets. This factor has been shown to affect farmers' decisions about adoption of new agricultural practices or inputs by the studies of Hicks and Johnson (1974), Harris (1972), Helleiner (1975), and Nordman (1969).

6. **Credit constraints:** Some of the theoretical studies mentioned earlier argue that the need to undertake fixed investments may prevent small farms from adopting innovations quickly. Capital in the form of either accumulated savings or access to capital markets is required to finance many new agricultural techniques. Thus, differential access to capital is often cited as a factor in differential rates of adoption as reported by Lowdermilk (1972), Lipton (1976), and Bhalla (1979). On the other hand, others have argued that lack of credit alone does not inhibit adoption of innovations that are scale neutral [Schutjer and van der Veen (1977), and von Pischke (1978)]. Binswanger and Sillers (1983)

conclude that this constraint is in important ways related to risks of farming itself, risk aversion, to problems of imperfect information about borrower, and to the absence of good insurance markets for crop-related risks.

7. **Tenure arrangement:** A number of empirical and descriptive studies have considered the effect of these factors and the proportion of farms rented on the adoption of HYV technology. However, empirical findings are conflicting. For example, Parthasarathy and Prasad (1978) concluded that tenants had a lower tendency to adopt HYVs than owners. On the other hand, nitrogen fertilizer use was the same for tenants and owners.

8. **Input supply constraints:** It is very obvious that HYV seeds will not be adopted unless both seeds and some fertilizer are readily available. In almost all cases, the high-yield potential of the seed can only be realized if at least some fertilizers are applied. Moreover, other inputs are also complementary to some degrees. Consequently, this raises the issue of complementary innovations. That is, some innovations (which may or may not have been introduced simultaneously) are complementary to a certain degree. Dalrymple (1978) and Burke (1979) suggested that HYV fertilizer package is more profitable and less risky if means of developing an assured and regulated water supply are also provided.

9. **Aggregate adoption over time:** This notion has been established in the early empirical studies of dynamics of diffusion in agriculture [see Beal and Bohlen (1957) and Rogers (1957)]. The first econometric

study of aggregate adoption over time was conducted by Griliches (1957), introducing economic variables to explain the diffusion of hybrid corn in the United States utilizing a logistic function of time for 132 corn-grower districts. Using Griliches's approach, Martinez (1972) obtains similar results for adoption of hybrid corn in Argentina. Jarvis (1981) estimates and predicts the diffusion of improved pastures in Uruguay using the nonlinear regression techniques for a modified logistic curve that includes beef and fertilizer prices as explanatory variables. In this category also belongs the work by Kislev and Shchari-Bachrach (1973).

B. Theory of Decision-Making under Risk and Uncertainty

Although agricultural economics has a long and fruitful history in the study of risk attitudes and providing for the improvement of decision making under risk, not until in the seventies was decision analysis under uncertainty regarded as an important topic. Jensen (1977) cites Heady's observation in 1949 that risks and dynamics of the firm was a neglected area of farm management study. Several other studies prior to the seventies had also acknowledged the linkage between farming risks, credit rations, and the consequences for resource adjustment and firm growth suggested by Johnson (1947) and Schultz (1949). Moreover, Heady's (1952) work on the principles of diversification of farm activities was also significant. Then, the seventies experienced further development in decision analysis under risks as documented by Halter and Dean (1971) and Anderson et al. (1977) in agriculture, followed by Roumasset et al. (1979) in agricultural development, and Valdes et al. (1979) in small farmer technology. Its revival is looming up again in the mid-eighties as documented in Barry (1984). Apparently, risk management analysis has regained its momentum in the more complex economic environment as prevailing today. Several models of risk have been advanced in the literature.

1. Risk models

Young (1984) classified risk models into three classes of decision rules, namely: (a) decision rules requiring no probability information, (b) safety-first rules, and (c) expected utility maximization.

a. **Decision rules without probability information** Four decision rules belong to this category (Halter and Dean, 1971): (i) minimax loss or maximin gain, (ii) minimax regret, (iii) Hurwicz α-index, and (iv) LaPlace principle of insufficient reason.

Criterion (i) considers only an action's worst possible outcome, either maximum loss or minimum gain, and then chooses the action whose worst outcome is the least harmful. The second rule selects the action with the smallest maximum regret where the regret for each combination of actions and states is the difference between the respective outcomes and the highest possible outcomes for that states. The Hurwicz α-index rule is formally stated as follows:

$$\text{Max } [I_j = \alpha (M_j) + (1 - \alpha)(m_j)] \tag{1}$$

where α is given by the decision maker subject to $0 < \alpha < 1$, M_j and m_j is the maximum and the minimum gain of action, respectively. The fourth rule culls the action with the highest expected outcome, based on equal probabilities of all outcomes.

The major objection to these models is that they are too restrictive connoting either (1) the decision maker has absolutely no subjective feelings or objective information about the probability distribution of outcomes, or (2) the decision maker has subjective probability information but neglects it.

b. **Safety-first rules** These rules are commonly employed in risk analysis as a lexicographic utility form, that is, they follow the sequential ordering of multiple goals where the highest priority goal must be achieved at a threshold level before considering the second goal, and so on. This can be translated as attaining a higher priority goal serving as a constraint on a goal with consecutively lower priorities. Typically, it is specified as chance of loss taking the form as:

$$[P(\pi \leq d)] \leq \alpha \tag{2}$$

where π is stochastic income for a particular action and d is a threshold income level to be satisfied with probability α. To see how close this rule and variance as measure of risk is depicted in Figure 2. By applying chance of loss definition, we unequivocally will order distribution 1a more risky than 2a, and 1b more risky than 2b, because α_1 is greater than α_2 in both figures. To the contrary, the variance definition will order 2a more risky than 1a, and 1b and 2b equally risky, because σ_1^2 is smaller than σ_2^2 in Figure 2, Panel a and σ_1^2 equals σ_2^2 in Panel b.

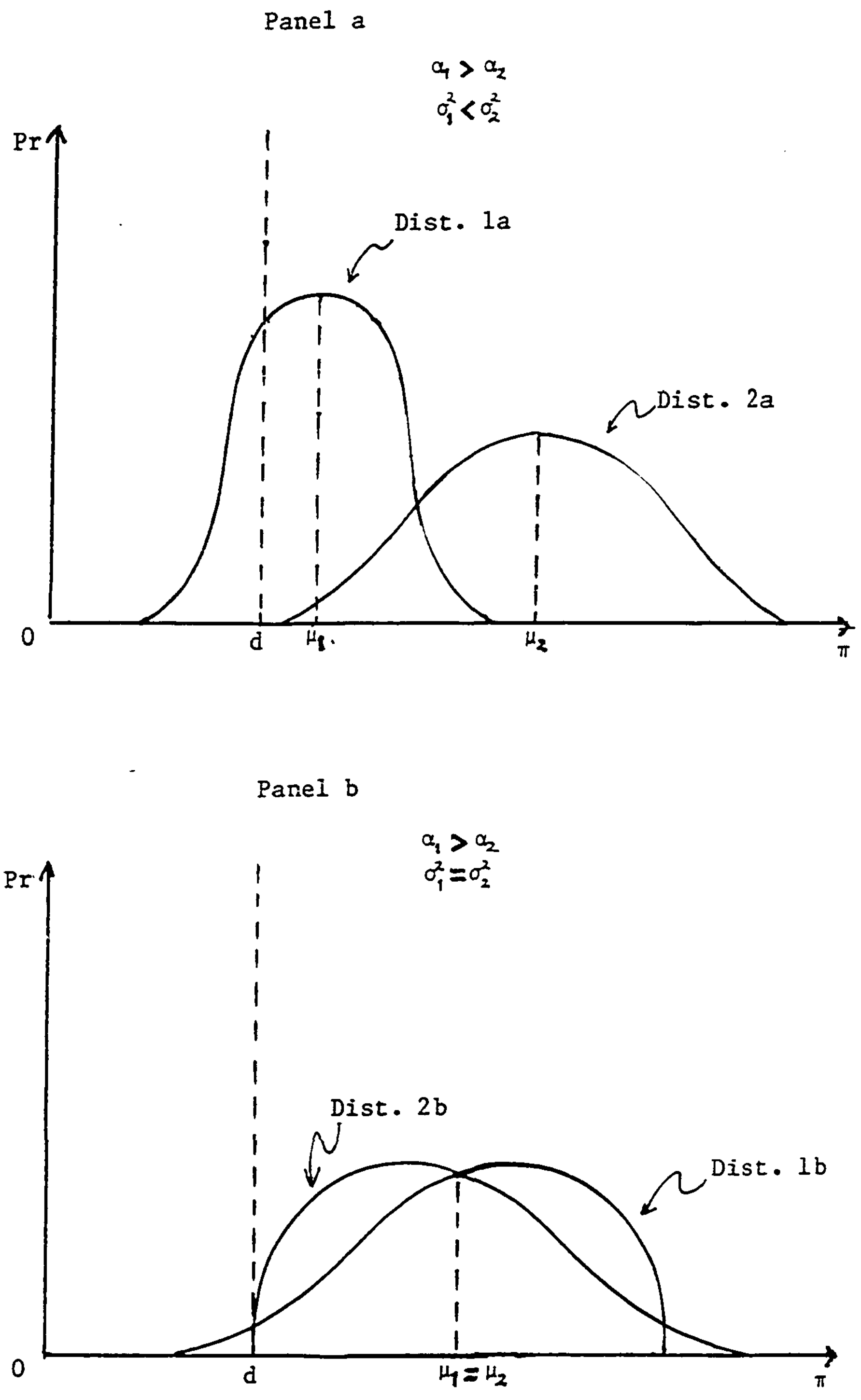

Figure 2. Chance of loss and variance measures of risk

In the literature, three types of safety-first rules have been advanced (Pyle and Turnovsky, 1970). The first rule (SF1), put forth by Shackle (1952) and Telser (1955-1956), supposes that an agent maximizes expected return ($\bar{\pi}$) subject to the constraint that the probability of a return less than or equal to a specific level (π-min) does not exceed a stipulated probability (P). This can be defined as:

$$\text{Max } \bar{\pi} \text{ s.t. } [(P_r\ (\bar{\pi} \leq \pi\text{-min})] \leq P\ . \tag{3}$$

The decision maker first decides a threshold level of income and the probability with which incomes must surpass this level. These are the key indicators under the rule and both characterizes the decision maker's attitude toward risk. For instance, the threshold income could be an income covering living expenses, debt repayment, and operating expenses. Then, the criterion proceeds by letting the decision maker considers various set of actions that fulfill the constraint, and finally, select among the actions based on the highest expected value. Figure 3 illustrates the procedure by taking curve AF as representing the lower confidence limits of income for a set of actions. Since plans A and F are below π-min, they are not going to be considered. Among the qualifying plans, C is the most preferred since it has the highest expected return.

The second safety-first rule (SF2) developed by Kataoka (1963) chooses a plan that maximizes income at the lower confidence limit (L) subject to the constraint that the probability of income being less than or equal to the lower limit does not surpass a specified value P. This

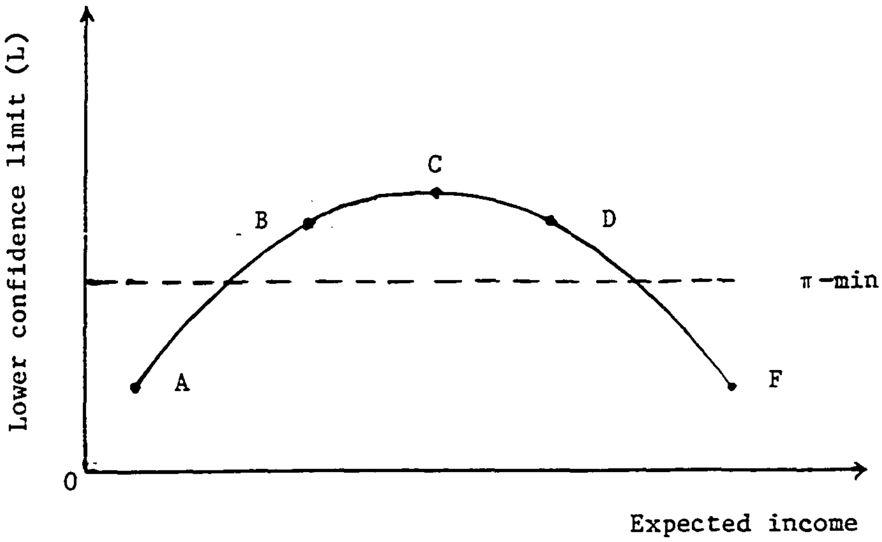

Figure 3. Lower confidence limits and safety-first

is expressed as:

$$\text{Max } L \quad \text{s.t. } [P_r(\pi < L)] \leq P \, . \tag{4}$$

Based on this rule, the optimal choice is plan C because it gives the highest return for confidence limit P, while still exceeding π-min. When the distribution depends on only two parameters such as the normal (Kunreuther and Wright, 1974), this rule can be expressed alternatively (Pyle and Turnovsky, 1970) as:

$$\text{Max } [E + F^{-1}(P^{*})\, S] \tag{5}$$

where F^{-1} denotes the inverse of the standard normal distribution function F, and E and S are mean and standard deviation of return, respectively. This form is equivalent to an earlier rule proposed for stochastic linear programming by von Moeseke (Roumasset, 1976).

The third safety-first rule (SF3) introduced by Roy (1952) chooses the plan with the smallest probability of yielding a return below some specified level. Formally, that is

$$\text{Min } [P_r \, (\pi < \pi\text{-min})] \quad (6)$$

Operationally, this rule is often represented in terms of its mean (E) and standard deviation (S) as

$$\text{Min } [(\pi\text{-min} - E)/S] \quad (7)$$

either by appeal to the Tchebychev inequality or by restriction to two-parameter distribution in general (Pyle and Turnovsky, 1970) or the normal distribution in particular (Chipman, 1973). Then, according to this rule, the optimum plan occurs where π-min is the greatest number of standard deviations away from the expected value. From Figure 3, this criterion is met by plan C.

These models have been popular among economists concerned with peasant agriculture partially due to the fact that they lend themselves to the possibility of incorporating subjective interpretation of probability to satisfy farmer subsistence levels.

c. <u>Expected utility rule</u> The mathematical form of expected utility which is also called Bernoulli's principle can be traced back to Cramer in 1728 and Bernoulli in 1738 who sought to explain the so-called St. Petersburg paradox.[1]

Unsatisfied with using monetary values in explaining many types of economic or financial behavior due to its inability to distinguish between decision maker's attitude toward additional wealth, for example, theoreticians developed a more general approach based on utility theory so that attitude under consideration of risk can further be explored. This theory facilitates a single-valued index of ranking alternative choices according to the preferences or attitudes of the decision maker.

Suppose an individual is confronted with sets of alternative choices A_1, A_2, ..., A_n with its conformable worth in monetary value is X_{ij} in the i-th state of nature, and further assume the individual can attach probabilities (either objective or subjective) to the various possible outcomes in a given state of each alternative choice $[P_r(S_i)]$. The choices are ranked based on assigned utility value on each monetary outcome X_{ij} generated from a subjective and arbitrary scaled utility function. Further, the utility for each possible outcome of an alternative choice is weighted by its probability and summed. This expected utility now becomes a preference index for the alternative choices. Finally, alternative choices are ranked based on their level of expected utility with the highest value being the most preferred. In a more formal form, the objective function is shown as

$$\text{Max } \{E[U(x)] = \Sigma\, U(X_{ij})\, P(S_i)\} \quad \text{for } j = 1, 2, \ldots, n \quad . \tag{8}$$

However, the axiomatic foundation of the theory had not been established until Ramsey's (1926) work which then was revived and extended by von Neumann and Morgenstern (1947) or Luce and Raiffa (1957). The axioms conceptualize how people behave towards risk and uncertainty. According to them, people are rational and consistent in choosing among risky alternatives. Given that is true, the theorem concludes that an optimal risky choice is based on the maximization of expected utility. The following is a summary of sets of axioms (see Anderson et al., 1977; Dillon, 1979; Hey, 1979; Robison et al., 1984):

(i) **Ordering.** For any two alternative choices, A_1 and A_2, the individual either prefers A_1 to A_2, prefers A_2 to A_1, or is indifferent between them.

(ii) **Transitivity.** If A_1 is preferred to A_2, and A_2 is preferred to A_3, then A_1 must be preferred to A_3.

(iii) **Substitutability.** If A_1 is preferred to A_2, and A_3 is some other choice, then a risky choice $PA_1 + (1-P)A_3$ is preferred to another risky choice $PA_2 + (1-P)A_3$, where P is the probability of occurrence.

(iv) **Certainty equivalent.** If A_1 is preferred to A_2, and A_2 is preferred to A_3, then some probability P exists that makes the individual indifferent to having A_2 for certain or receiving A_1 with probability P and A_3 with probability (1-P). Thus, A_2 is the certainty equivalent of $PA_1 + (1-P)A_3$.

If these axioms are satisfied, a utility function can be derived solidifying the individual's preferences (Borch, 1968; Hey, 1979). Hence, the decision maker's utility functions captures the preference ordering over a set of outcomes based on his degree of belief and his degree of preference. This utility function is typically specified in terms of wealth, denoted by W and is assumed to be monotonically increasing, i.e., dU/dW is greater than zero, indicating a positive marginal utility for wealth. The decision maker's attitude toward risk is then inferred from the relationship of his wealth and his utility. An individual with a concave utility function is said to be a risk averter, meaning that he prefers a choice with a perfectly certain return to another choice with an equal, but uncertain, expected return (Panel a, Figure 4). It follows immediately that certainty equivalent of a choice is always less than its expected monetary value by a positive risk premium (π) which remunerates the risk averter in utility terms for undertaking the risky choice. Risk indifference or risk neutral individual is exhibited by a linear utility function suggesting that the individual is indifferent to a certain return and an equivalent uncertain expected return. This signifies that certainty equivalent of risky prospect equals its expected monetary value (Panel b, Figure 4). In this case, then, the risk premium is zero.

Panel c of Figure 4 portrays a risk-preferring individual having a convex utility function which implies that he chooses an uncertain expected return rather than an equivalent certain return. In this case, the certainty equivalent is always greater than its expected monetary value which gives negative risk premium.

However, the classification above by no means is an exhaustive grouping. An individual could have a utility function that has some concave segments and some convex segments as has been pointed out by Friedman and Savage (1948, 1952). This is depicted in Panel a of Figure 5 where the figure starts as concave in the first stage, turning to be convex in the next stage and winding up concave again. This purports that at lower levels of wealth with this sigmoid-type utility function

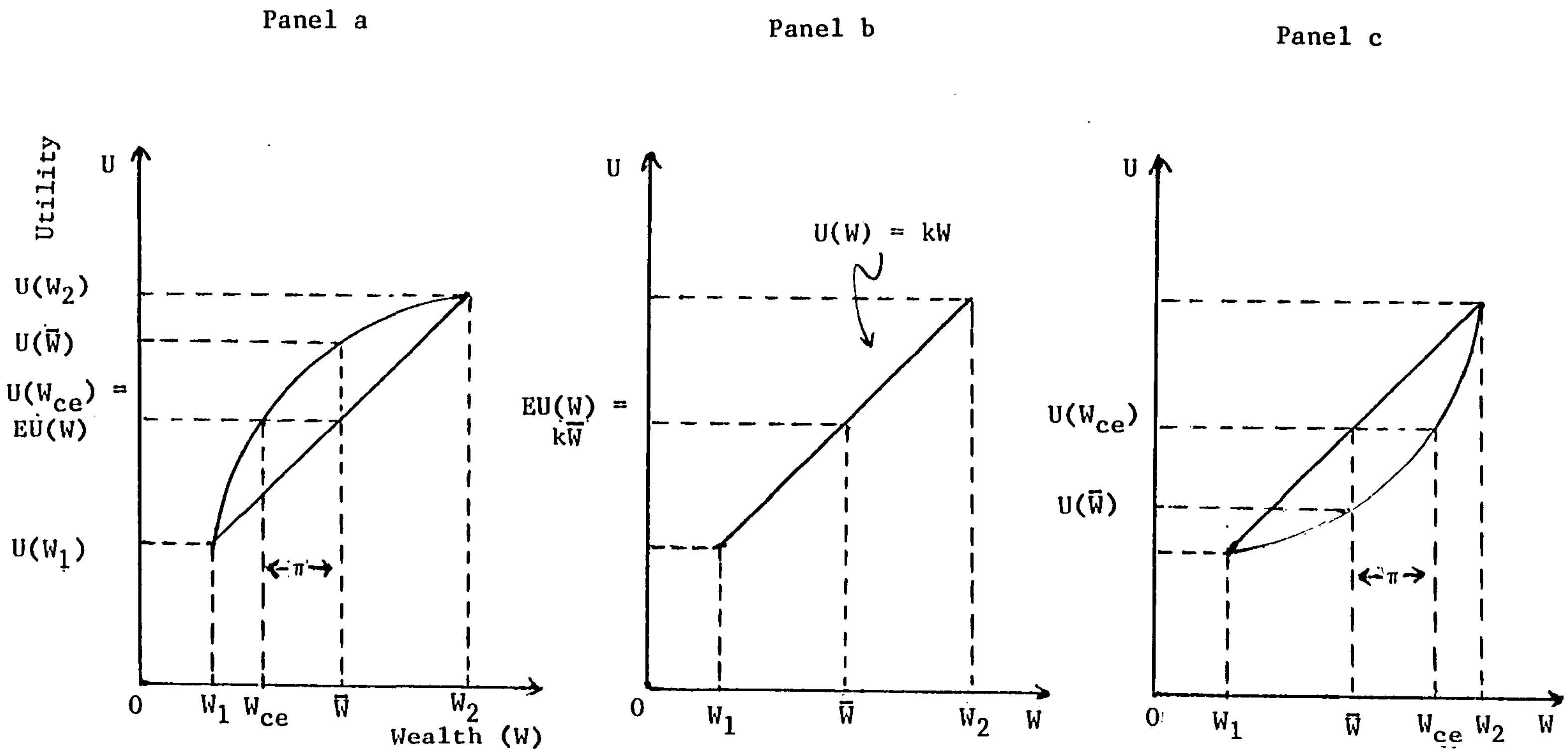

Figure 4. Utility functions with diminishing, constant, and increasing marginal utility

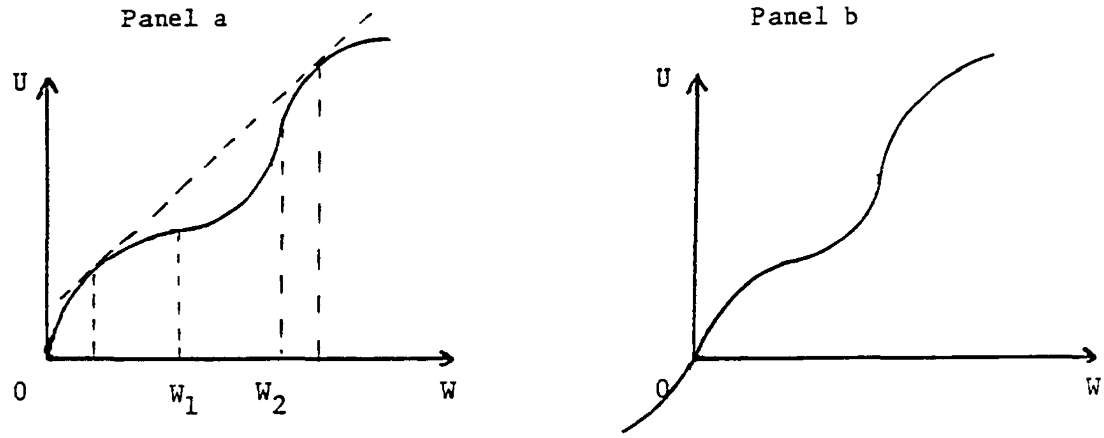

Figure 5. Multi-inflection points utility function

is initially risk averse up to W_1 level of wealth and turns to be a risk lover in W_1W_2 range. Then, starting at the wealth level of W_2 the individual becomes a risk-averter again. Still, there is another form of utility function suggested by Markowitz (1952) which has three inflection points purporting the individual first behaves as risk-preferring, then risk-averter, followed by risk-loving again before becoming eventually risk-averter (Panel b, Figure 5). In spite of theoretical appeals offered by these two possibilities, it seems a single inflection point over the range of wealth is regarded as the closest representation of individual attitude toward risk as predominantly shown in the current economic literature and it is the degree of risk aversion that may differ among individuals.

Having established the relationship between utility functions and risk attitudes, an individual behavior toward risk can be deduced from the second derivative of this utility function with respect to wealth, namely that negative, zero, or positive second derivative will indicate risk aversion, risk indifference, or risk preference of the individual, respectively. The problem, however, is the magnitude of second derivative cannot be used for interpersonal comparisons of risk aversion due to the fact that an individual's utility function is only unique up to a linear transformation. Thus, it can be arbitrarily transformed by multiplying the utility function by a positive number. To facilitate interpersonal comparisons, three measures have been proposed in the literature:

(1) Absolute risk aversion (A) is defined as:

$$A(W) = - U''(W)/U'(W) \tag{9}$$

a unit-free measure of the local concavity of the utility function [Primes denote derivative, e.g., $U' = dU(W)/dW$ and $U'' = d^2U(W)/dW^2$, etc.], where W is current wealth.

(2) Relative risk aversion (R) is expressed as:

$$R(W) = - W[U''(W)/U'(W)] = WA\ . \tag{10}$$

(3) Partial risk aversion (P) is formalized as:

$$P(W) = - X[U''(W+X)/U'(W+X)] = XA \tag{11}$$

where X is an outcome in the prospect under consideration.

A and R indices are proposed by Pratt (1964), and independently by Arrow (1964), while S was suggested independently by Menezes and Hanson (1970) calling it partial risk aversion, and by Zeckhauser and Keller

(1970) who named it size-of-risk aversion. These measures can be used to test the hypothesis concerning responses of risk aversion to changes in wealth or the size of the outcome.

2. Measuring risk attitudes

In studying risk attitudes empirically, several approaches have been offered in the literature classified into five categories:

a. **Direct elicitation of utility functions (DEU)** This procedure relies on direct contact with individuals to formulate their risk attitudes utilizing single-valued utility index, lexicograph, utility, or broader concept of multiple goals. Three variates belong to this group, namely, the von Neumann-Morgenstern method, the modified von Neumann-Morgenstern method, and the Ramsey method, all employing the certainty equivalent axioms of the expected utility model in repeated applications of hypothetical gambles (Anderson, 1979). The problem with this procedure is that it can be bias from different interviewers, preferences for specific probabilities, confounding from extraneous variables, negative preferences toward gambling, absence of realism in the game setting, lack of time and experience of the participants to become familiar with the hypothetical choices, and compounding of errors in the elicitation process (Roumasset, 1976; Binswanger, 1980; Robison, 1982). Lin and Chang (1978) also pointed out that an inappropriate specification of the utility function can also adversely influence implications concerning risk attitudes.

These shortcomings have helped to stimulate the refinings, extending and generalizing the DEU methods to appropriately typify risk attitudes (Halter and Mason, 1978). However, the DEU method is very costly for carrying out economic analysis. In less developing countries, some empirical studies of risk attitudes that implement the DEU have been documented in the works by O'Mara (1971) in Mexico, Roumasset (1976) in Philippines, Moscardi and de Janvry (1977) in Mexico, Dillon and Scandizzo (1978) in Brazil, Arcia (1980) in Colombia, Binswanger (1980) in India, Hamal and Anderson (1982) in Nepal, and Herath et al. (1982) in Sri Lanka, among others.

b. **Risk efficiency approach** This approach provides a partial ordering of alternative choices based on its ability to segment the decision alternative into two mutually exclusive sets, namely, an efficient set containing the preferred choice of every individual whose preferences conform to the restrictions associated with the criterion, and an inefficient set comprising the unpreferred alternatives. The advantage of this approach is that direct preference measurements need not be made and if enough can be eliminated, a final choice can be formulated by direct comparison of the outcome distribution of those that remain. Four groups of risk efficiency models are summarized below:

(i) **First degree stochastic dominance (FSD).** This rule is the simplest and most universally applicable efficiency criterion. It states that given two alternative outcomes with their distributions defined by cumulative distribution function (CDF), F(y), and G(y), F(y) is preferred to G(y) if

$$F(y) \leq G(y) \tag{12}$$

for all possible values of y and if the inequality is strict for some value of y. Graphically, this condition translates as the CDF of dominant distribution must always lie below that of the dominated distribution. In Figure 6, for example, F(y) dominates G(y) by FSD rule, but neither F(y) nor G(y) can be ordered with respect to H(y). FSD holds for all individuals who prefer more to less. This rule was proposed by Quirk and Saposnik (1962), Fishburn (1964), Hadar and Russell (1969), and Hanoch and Levy (1969). This approach has been implemented by Valdes and Franklin (1979) for evaluating the performance

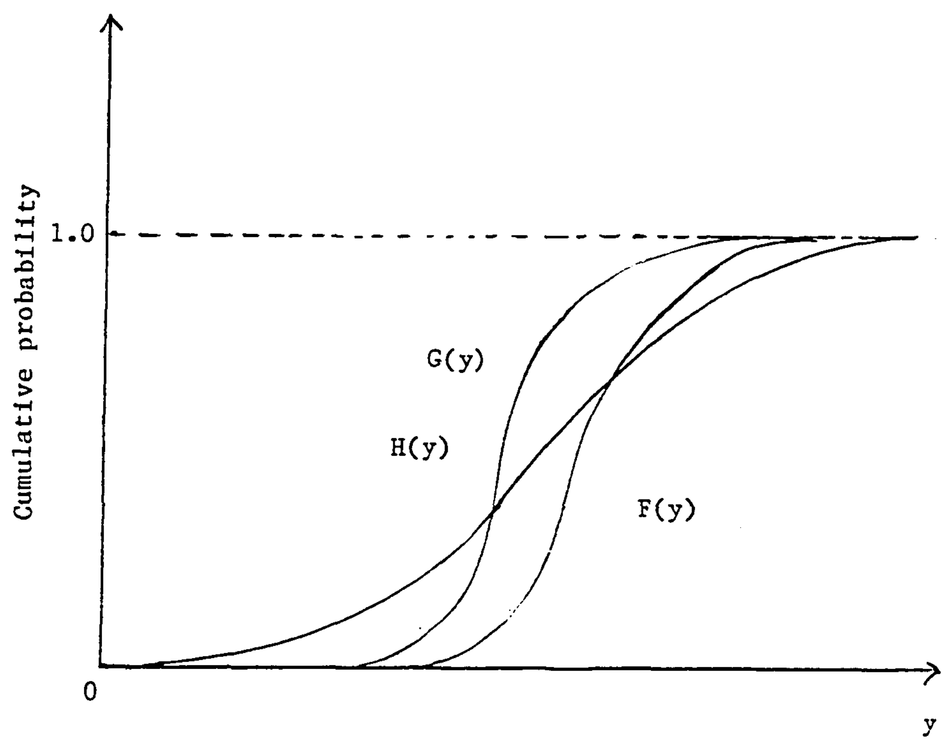

Figure 6. First and second degree stochastic dominance

of new ranch technologies in Colombia and by Grisley and Kellogg (1983) to determine if farmers' crop production plan agreed with their expectations of the net income variable in Thailand.

(ii) **Second degree stochastic dominance** (SSD). This rule is more discriminating than FSD. It says that F(y) is preferred to G(y) if

$$\int_{-\infty}^{\infty} F(y)dy \leq \int_{-\infty}^{\infty} G(y)dy \qquad (13)$$

for all possible values of y and if the inequality is strict for some value of y. Grapnically, this condition means that the accumulated area under dominant distribution is always less than or equal to that of under the dominated distribution. In Figure 6, for instance, F(y) dominates either G(y) or H(y) so F(y) is the SSD efficient set for these alternatives. However, when only G(y) and H(y) are compared, neither dominates the other by SSD since the accumulated area under G(y) is less than the area under H(y) for low values of y, while the opposite condition occurs at high values of y. SSD holds for all individuals whose utility functions have positive, non-increasing slopes at all outcome levels. The rule was discovered independently by Fishburn (1964), Hammond (1968), Hadar and Russell (1969), and Hanoch and Levy (1969).

Among empirical studies that implemented this rule are Valdes and Franklin (1979), and Grisley and Kellogg (1983).

(iii) **Mean-variance (E-V) efficiency.** This rule requires that the individual is risk averse and the outcome distributions are normal or the individual's utility function is quadratic. Thus, E-V efficiency criterion can be stated in terms of only two moments, means and variances. Outcome distribution F with mean E_F and variance V_F dominates distribution G with mean E_G and variance V_G, if

$$E_F \geq E_G \text{ and } V_F \leq V_G \tag{14}$$

and if one of these two inequalities is strict. This procedure was put forth by Markowitz (1959) and is widely used for its analytical and computational convenience by using quadratic programming.

Quadratic risk programming has been employed in many studies to evaluate optimum farm organizations under conditions of risky choice such as Freund (1956), Halter and Dean (1971), Thomas et al. (1972). Applications in less developing countries are the works by Khatikarn (1981) in Thailand, Mohayidin (1981) in Malaysia, and Singh and Zilberman (1984) in India, among others.

(iv) **Mean-absolute (E-A) deviation efficiency (MOTAD).** This criterion is an approximation to E-V efficiency rule modeled in linear programming framework. It also assumes that the individuals are risk averter. Outcome distribution F with mean E_F and mean-absolute deviation A_F, dominates distribution G with mean E_G and mean-absolute deviation A_G, if

$$E_F \geq E_G \text{ and } A_F \leq A_G \tag{15}$$

and if one of the two inequalities is strict, where the mean-absolute deviation, A, is defined as

$$A = \frac{1}{n} \Sigma |y_i - E_y| \tag{16}$$

and n is the number of observed outcome levels, y_i is the i-th observed outcome level with its expected value E_y. This rule was developed by Hazell (1971). This rule has been applied in numerous studies such as Schluter (1974), Simmons and Pomareda (1975), Sanders and Dias de Hollanda (1979), Kutcher and Scandizzo (1981), O'Brien (1981), and Musser et al. (1984).

c. **Risk interval approach** Due to the limitations possessed by the DEU, King and Robison (1981a,b) indicate that the DEU method is not accurate enough to measure a uniquely defined utility function. Then an interval measure of risk attitudes is proposed accounting for possible errors in the measurement process. This is related to the second approach in the sense that it uses stochastic dominance principle in a more general case that is with respect to not only strategies but also a function inspired from the work by Meyer (1977a,b). It is a more discriminating efficiency criterion that allows for greater flexibility in representing preferences and it also does not require an assumption of normality. The method is based on identifying a confidence interval for the Arrow-Pratt measure of absolute risk aversion that is estimated by asking individuals to order pair-wise comparisons of probability density functions.

This rule has since been applied in many studies such as King and Robison (1982), King and Oamek (1983), Pederson (1984), and Zacharias and Grube (1984).

d. **Experimental methods** This approach involves the use of synthetic experiences through gambling or gaming experiment in which the attitude towards risk is ascertained using a partial risk aversion measure. Each participant was offered a series of choices from sets of alternative risks. Upon identifying his preferred alternative, the participant was asked to toss a coin whose outcome then determined whether the participant receive the high or low return for the designated alternative. Since the alternatives offering higher expected return were designed to have a larger spread, the participant's revealed preference may be viewed as a reflection of his preferences between risk and expected gain (Binswanger, 1980; Binswanger and Sillers, 1983).

This method has also been implemented by similar studies such as Grisley (1980) in Thailand, Sillers (1980) in Philippines, and Walker (1980) in El Salvador.

e. **Observed economic behavior (OEB)** This method focuses on the relationship between the actual behavior individuals and the behavior predicted from empirically specified models. For instance, the determination of effects of a farmer's risk attitude on fertilizer levels when crop yield is a random variable. Following approaches by Anderson et al. (1977) and Young et al. (1979), expected utility maximization objective results to a first order condition,

$$E(MVP_i) = MFC_i + R_a I_r \tag{17}$$

where $E(MVP_i)$ denotes expected marginal value product (MVP) of input i, MFC_i is nonstochastic marginal cost (MFC) of input i, and $R_a I_r$ encapsulates a risk adjustment based on the farmer's risk aversion coefficient (R_a), and the marginal contribution to risk of additional input use (I_r). If I_r is assumed to be positive, risk aversion ($R_a > 0$) implies a positive risk adjustment, that is, a risk averse farmer will stop short of equating E(MVP) to MFC.

Rearranging Equation [16], a theoretical approach for measuring R_a empirically is given by

$$R_a = [E(MVP_i) - MFC_i]/I_r \quad . \tag{18}$$

Nonetheless, estimating I_r is difficult without making restrictive assumptions about stochastic events.

The benefits of using the OEB method are that it can generate quantitative measures of risk aversion, it can handle large amounts of sample data, it is less costly than interviewing many objects, and it avoids measuring risk attitudes from hypothetical gaming situations. However, the major drawback is that it is subject to several inference problems. The OEB method attributes the entire difference between actual firm performance and performance predicted by an assumed objective to the decision maker's risk attitude even though in reality many other factors besides risk determined observed behavior.

Empirical studies adopting this approach are exemplified by Behrman (1968) in Thailand, Just (1974) in U.S.A., Wolgin (1975) in Kenya, Wiens (1976) in China, Moscardi and de Janvry (1977) in Mexico, Anderson and Griffiths (1981) in Australia, Lins et al. (1981) in U.S.A., and Rosegrant and Roumasset (1983) in Philippines. A modification of this methodology is employed in this research.

NOTES TO CHAPTER III

[1] Cramer proposed this theory in 1738 (letter to Bernoulli's cousin cited in Bernoulli, 1954).

IV. EMPIRICAL ESTIMATION METHODS

This chapter discusses the models and the analytical methodology that will be used as empirical implementation of the study. It explains the specification, estimation and the source and the type of data used. Section A focuses on justification of the chosen specification and estimation procedure for farm-level input demands. Section B briefly develops the theoretical foundations of production risk in order to adequately represent the nature of the probability distribution of output and its important economic implications. The final section presents a brief description, source, and the type of data used in the analysis.

A. Farm-level Input Demands Adjusted for Seed Selectivity Bias

Analysis of input demand from micro data on Indonesian rice farms is quite scarce. One study that is specifically concerned with fertilizer demand in Asian rice economy including Indonesia is done by David (1976). In her model, the relative price of fertilizer to rice was one of the arguments in the equation which supposedly reflects the market force influencing farmer economic behavior. The coefficient for the price ratio has the correct sign but is not significant, however. Moreover, if seed selection is taken into account from the fact that farmers do not use the same type of seed, empirical research is hardly prevalent. Even though there may have been some attempts to consider this seed variety, most of them assume that seed selection is an independent variable rather than a decision variable. Therefore, those studies neglect the possibility that farmers can respond to price changes not only by adjusting their variable input use but also by switching to different seed varieties. This is theoretically inappropriate. Two most recent studies using the second approach in the context of rice production are by Sumodiningrat (1982) and Pitt (1983). Sumodiningrat's study applies a transcendental logarithmic (translog) cost function covering a broad range of inputs, variable and fixed. Pitt's study employs a translog profit function. These two studies are in line with the induced-innovation hypothesis in part of farm producers proposed by Hayami and Ruttan (1985) arguing that changes in the relative prices of new inputs will induce farmers to search for technical alternatives that save the increasingly scarce factors of production where high-yielding varieties are essentially an input designed to facilitate the substitution of fertilizer (or other inputs) for land.

One consequence of the inability to consider this switching process, namely, seed selection from a traditional to an improved variety is a tendency to underestimate the parameters derived from nonswitching regime as suggested by Pitt (1983). This study will not employ profit maximizing objective but instead implement a cost minimizing rule due to the fact that profit maximization might not be a suitable hypothesis in the Indonesian case due to the subsistence characteristic of farms. Therefore, the cost function approach is much more useful than the profit function approach from the viewpoint of generating systems of factor demand equations consistent with cost minimization. It relates some a priori restrictions imposed by profit function and is easier to estimate. Nevertheless, both approaches use duality theorems between each function and the production function. Input demand elasticities are derived by using Shephard's lemma [see Shephard (1970), Jorgenson and Lau (1974), Diewert (1974), Silberberg (1979), and Beattie and Taylor (1985)].

Operationally, we assume that farmers have to select between two types of rice seed, high-yielding (HYV) or modern (MV) varieties and local (LV) or traditional (TV) varieties with the consideration of minimizing farm production cost for a given output level. For each combination of fixed and variable input prices, there is a variable cost (and optimal input use) for the two seeds. A farmer will choose to plant MV seeds if the reservation variable cost incurred by doing so is less than the variable cost by growing traditional variety seed.

The model considered here contains two regimes described by a set of simultaneous equations as follows:

$$C_{mi} = P_i \gamma_m + Z_i \delta_m + \varepsilon_{mi} \tag{19}$$

$$C_{ti} = P_i \gamma_t + Z_i \delta_t + \varepsilon_{ti} \tag{20}$$

$$I^* = (C_{ti} - C_{mi}) \lambda - \varepsilon_i \tag{21}$$

where P_i is a vector of variable input prices; Z_i is a vector of fixed input and output level; C_{mi} and C_{ti} represent variable costs under the MV and TV regime, respectively, γ_m, γ_t, δ_m, δ_t, and λ are vectors of parameters; and $\varepsilon_{mi} \sim N(0, \sigma_m^2)$, and $\varepsilon_{ti} \sim N(0, \sigma_t^2)$. Equations (19) and

(20) are variable cost functions. Equation (21) is the decision criterion determining whether or not the farmer to plant MV seeds, and I^* is an unobserved variable. However, a dummy variable, I_i is observed having the value of 1 if the farmers grows MV, and 0 otherwise, that is

$$I_i = \begin{cases} 1 \text{ if } I_i^* \geq 0 \\ 0 \text{ otherwise} \end{cases} \quad . \tag{22}$$

By further assuming that a farmer grows either MV or TV, we observe associated costs incurred taking values

$$\begin{aligned} C_i &= C_{mi}\ , \quad \text{iff} \quad I_i = 1 \\ C_i &= C_{ti}\ , \quad \text{iff} \quad I_i = 0 \end{aligned} \tag{23}$$

The population regression function for equation (19) then is written as

$$E(C_{mi}|P_i,\ Z_i) = P_i\ \gamma_{mi} + Z_i\ \delta_{mi} \tag{24}$$

which can be estimated without bias from a random sample of the population of rice farmers. The regression function for the incomplete sample (MV farmers only) is written as

$$\begin{aligned} &E(C_{mi}|P_i,\ Z_i,\ \text{sample selection rule}) = \\ &\quad P_i\ \gamma_{mi} + Z_i\ \delta_{mi} + E(\varepsilon_{mi}|\text{sample selection rule})\ . \end{aligned} \tag{25}$$

If the conditional expectation of ε_{mi} on the right-hand side of equation (25) equals zero, a regression on the incomplete sample will provide unbiased estimates of γ_{mi} and δ_{mi} (Heckman, 1976). However, it is very unlikely that both

$$E(\varepsilon_{mi} | I_i = 1) = 0 \quad \text{and} \quad E(\varepsilon_{ti} | I_i = 0) = 0 \;. \tag{26}$$

This can only occur in a very special situation (Lee, 1976). In general, C_{mi} and C_{ti} cannot be consistently estimated by ordinary least squares using observed expenditures.

The parameters of the model are estimated by specifying equations (19) and (20) in a translog form as

$$\begin{aligned} LnC = {} & a_0 + \sum_{i=1}^{m} a_{0i} LnP_i + a_y LnY + \sum_{k=1}^{r} b_{0k} LnZ_k + \frac{1}{2} \sum_{k=1}^{m} \sum_{j=1}^{n} a_{ij} LnP_i \; LnP_j \\ & + \sum_{i=1}^{m} a_{iy} \; LnP_i \; LnY + \frac{1}{2} a_{yy} \; (LnY)^2 + \sum_{i=1}^{m} \sum_{k=1}^{n} b_{ik} LnP_i \; LnZ_k \\ & + \frac{1}{2} \sum_{k}^{r} \sum_{l}^{s} d_{kl} \; LnZ_k \; LnZ_l + \sum_{k}^{r} d_{ky} \; LnZ_k \; LnY \end{aligned} \tag{27}$$

where again C is variable cost, P_i is a vector of variable input prices, Z_i is a vector of fixed input and Y is output level[1]. This cost function must satisfy the following restrictions:

1. <u>Symmetry</u>: (a) $a_{ij} = a_{ji}$, (b) $a_{iy} = a_{yi}$, and (c) $d_{kl} = d_{lk}$ (27a)

2. <u>Homogeneity</u>: (a) $\sum_{i=1}^{m} a_{0l} = \sum_{k}^{r} b_{0k} = 1$, and

$$\text{(b)} \qquad \sum_{j=1}^{m} a_{ij} = \sum_{i}^{m} a_{iy} = \sum_{i}^{m} b_{ik} = \sum_{k}^{r} d_{kl} = \sum_{k}^{r} b_{ik} = \sum_{k}^{r} d_{ky} = 0 \tag{27b}$$

By employing Shephard's lemma, a specification for factor shares (S_i) can be obtained as follows:

$$S_i = \frac{LnC}{LnP_i} = a_i + \sum_{j=1}^{n} a_{ij} LnP_j + a_{ij} LnY + \sum_{k=1}^{r} b_{ik} \; Ln \; Z_k \tag{28}$$

where S_i is the ratio of variable expenditures for the i-th input to farm production expenses. Therefore, elasticity demand for inputs are estimated from the estimation of parameters in equation (28).

Cost function (25) is estimated by the two-stage method described by Heckman (1976) and Lee (1976). Substituting the cost functions (19) and (20) into the selection criteria (21),

$$I_i^* = \theta_0 + P_i \; \theta_1 + Z_i \; \theta_2 - \varepsilon_i^* \; . \tag{29}$$

Equation (29) is estimated as a typical probit equation allowing the possibility of computing the probability that any farmer has missing data on C_{mi} or C_{ti} (Pitt, 1983). The estimates demonstrate how prices and fixed factors affect the probability of adopting MV. Following further the two-stage method, if the joint density of ε_{mi}, ε_{ti}, and ε_i is multivariate normal, then the conditional expectation on the right hand side of (25) is

$$E(\varepsilon_{mi} | I_i = 0) = \sigma_{1\varepsilon}^* \; [\; - \frac{f(\phi_i)}{F(\phi_i)} \;] \tag{30}$$

where F is the cumulative distribution of standard normal random variable and f is its density function, both evaluated at ϕ_i. $F(\phi_i)$ is the probability that C_{mi} is observed. In principle, then the two-stage procedure uses $\{-f(\phi_i)/F(\phi_i)\}$ and $\{f(\phi_i)/[1-F(\phi_i)]\}$ as regressors representing seed selection variable in the MV and TV cost function, respectively, to purge them of bias. ϕ_i are estimated by $\hat{\theta}_0 + P_i\hat{\theta}_1 + K_i\hat{\theta}_2$, obtained from the estimated probit reduced-form equation (29).[2]

B. Production under Risk

In the previous chapter, the importance of risk and uncertainty in affecting adoption behavior of the farmer has been described. This section focuses on the specific issue of incorporating the risk element in the production function.

Apart from the implicit consequence of the estimation procedure, hypothesis testing and drawing conclusions from the duality of the neoclassical production function discussed in Section A, another restrictive limitation embodied by many models is the failure to recognize the fact that output, and hence profit, might be stochastic. Consequently, it might be more realistic to assume that the producer is maximizing expected profit, or expected utility, which could for example be a function of the mean and variance of profit. Production risks arise from the variability of yields and technology or as Magnusson (1969) states, from the uncertain performance of production factors. Three major categories of risk and uncertainty in this respect are: (i) technological risk, (ii) weather risk, and (iii) price risk. All three are important in the traditional agriculture to low income nations (Mellor, 1969).

The concept of stochasticity in production is not a new topic in the economic literature [see Marschak and Andrews (1944), Day (1965), Fuller (1965), Zellner, Kmenta, and Dreze (1966), Anderson (1973), Pope and Just (1977), Just and Pope (1978, 1979a, 1979b), Antle (1983), Blair and Lusky (1975)]. This research is primarily concerned with the implication of the inclusion of risk measured by moments of output distributions as a basis for portfolio choice. In particular, the effects of these distribution moments on farm input decision theory will be investigated.

Just and Pope (1979a,b) have shown that the usual specifications of production functions with appending of additive or multiplicative random error terms have severe restrictions with respect to risk when risk is measured as the variance of output distribution. Naturally, some inputs may have decreasing effect on production risk such as pesticides and possibly certified seeds. However, these specifications do not allow for a possibility of decreasing risk since they are generally designed to measure mean productivity and typically ignore the possibility that higher moments may also be functions of input use. This has been empirically shown to be true by Day (1965), Anderson (1973), Roumasset (1976), Just and Pope (1979a,b), Nikiphoroff (1981), Antle and Goodger (1984). This assertion can be demonstrated as follows. Let

$$y = m(X, \alpha)e^{\varepsilon} \tag{31}$$

where y is output, $X = (X_1, X_2, \ldots, X_k)$ is a vector of inputs, α is a conformable parameter vector and ε is a random error. Though this form is simple, it has little theoretical justification and can be shown to impose a number of arbitrary restrictions on the stochastic structure of the production process. Letting E(.) denote the mathematical expectation operator, the mean of output

$$\mu_1 = E(y) = m(X, \alpha)\ E(e^{\varepsilon}) \tag{32}$$

and the variance is

$$\mu_2 = E[y - E(y)]^2 = m(X, \alpha)^2\ E[e^{\varepsilon} - E(e^{\varepsilon})]^2 \tag{33}$$

and in general, the i-th moment about μ_1 is

$$\mu_i = m(X, \alpha)^i\ E[e^{\varepsilon} - E(e^{\varepsilon})]^i\ . \tag{34}$$

Equation (32) implies that the mean and the higher moments of the probability distribution of output are functions of inputs through the function $m(X, \alpha)$. The set of restrictions, or maintained hypothesis, implied by this model can be expressed in terms of the elasticities of moments with respect to inputs. From equation (34), for $\mu_i \neq 0$,

$$\eta_{ij} = \frac{\delta\mu_i/\mu_i}{\delta X_j/X_j} = i\ \frac{\delta m(X,\alpha)/m(X,\alpha)}{\delta X_j/X_j} = i\ \eta_{1j}, \quad i \geq 2\ . \tag{35}$$

In other words, the elasticity of the i-th moment with respect to the j-th input, η_{ij}, is proportional to the mean production elasticity η_{1j}. The second frequently used specification is the additive error model

$$y = m(X, \alpha) + \varepsilon\ . \tag{36}$$

Typically, ε is assumed to be independently and identically distributed across all observations and distribution of ε is assumed not to depend on X. Under this specification, only the mean of the output distribution is assumed to be a function of inputs, all others moments independent of X. Thus, model (36) implies that $\eta_{ij} = 0$ for all $i \geq 2$.

Just and Pope (1978) have suggested a more flexible stochastic specification than model (31) and (36) by using the Heteroskedastic model proposed by Harvey (1976). This is done by decomposing random error ε in equation (36) with heteroskedastic structure as

$$\varepsilon = h(X, \beta)u \tag{37}$$

where u is an independently and identically distributed error term. This will allow for a relation between uncertainty and inputs not solely determined through the relationship of input and expected output. Moreover, $h(X, \beta)$ is possibly linearly homogeneous allowing sufficient flexibilities such that the signs and magnitudes of hh_i and $h_j h_{jj}$ (h_i and h_{ii} denotes the first and second derivative of h with respect to i) are not predetermined a priori and so inputs with decreasing risk effect can be detected.

This model has an intuitive appeal in the empirical analysis of production economics. Nevertheless, it has one weakness that has been pointed out by Antle (1981), Nikiphoroff (1981), and Antle (1983). This model imposes restrictions on the second and higher moments just as the models (31) and (36) impose on all moments. Namely, with equation (37), $\varepsilon = h(X, \beta)u$,

$$E(\varepsilon^i) = h(X, \beta)^i \, E(u^i) = \mu_i \, . \tag{38}$$

For $i > 2$ and $E(u) \neq 0$ the parameters of the i-th moment are directly related to the parameters of the second moment, particularly

$$\eta_{ij} = \frac{\delta\mu_i/\mu_i}{\delta X_j/X_j} = i\ \frac{\delta h(X,\beta)/h(X,\beta)}{\delta X_j/X_j} = \frac{i}{2}\ \eta_{2j}\ , \quad i > 2 \tag{39}$$

Therefore, the elasticity of each higher nonzero moment with respect to an input is directly proportional to the elasticity of the second moment with respect to that input. He then proposed an alternative linear moment model as follows:

$$y = X\ \beta_1 + \varepsilon \tag{40}$$

$$\mu_1 = E(y) = X\ \beta_1\ . \tag{41}$$

Defining $\mu_i = E(u^i)$, $i \geq 2$, as the i-th moment of y about its mean μ_1. Then let the i-th moment function be

$$\mu^i = X\ \beta_i + v_i\ , \quad E(v_i) = 0, \quad i \geq 2 \tag{42}$$

so that $\mu_i = X\ \beta_i$ for all i. The model represented by equations (41) and (42) contains a different parameter vector β_i for each moment function and thus does not impose restrictions on the β_i either within or across moments.

In spite of the drawback possessed by the Just and Pope model about the consequence on higher moments, it will be used in empirical estimation of production function specified later.

This can still be justified when we assume that output follows a two-parameter distribution such as the normal distribution because most empirical production studies assume normality anyway. Moreover, Antle's model certainly necessitates a more complicated estimation procedure. Operationally assuming a traditional production function in Cobb-Douglas

(C-D) form,

$$y_i = \alpha_0 \left(\prod_{k=1}^{K} X_k^{\alpha_k} \right) e^{\varepsilon_i} \tag{43}$$

where y_i is output and $X_{ik} > 0$ is the k-th input, ε_i is the stochastic random error such that $E(\varepsilon_i) = 0$, and Var $(\varepsilon_i) = \sigma^2 > 0$. Then the marginal effect of input on production variability can be shown as follows:

$$\text{Var } (y) = [\alpha_0 (\prod_{k=1}^{K} X_k^{\alpha_k})]^2 \text{ Var } (e^{\varepsilon}) \tag{44}$$

$$\frac{\delta \text{Var } (y)}{\delta X_k} = \frac{2\alpha_t \; [\alpha_0 (\prod_{k=1}^{K} X_k^{\alpha_k})]^2}{X_k} \text{ Var } (e^{\varepsilon}) \quad . \tag{45}$$

Equations (43) and (45) can be estimated using OLS after linearizing them by logarithmic operators. A more flexible form of production function proposed by Just and Pope (J-P), is specified as:

$$y_i = \alpha_0 \left(\prod_{k=1}^{K} X_k^{\alpha_k} \right) + \beta_0 \left(\prod_{k=1}^{K} X_k^{\beta_k} \right) u_i \; . \tag{46}$$

Then by the same token, the marginal effect of input on production variability can be derived as follows:

$$\text{Var } (y_i) = [\beta_0 \left(\prod_{k=1}^{K} X_k^{\beta_k} \right)]^2 \text{ Var } (u_i) \tag{47}$$

and

$$\frac{\delta Var(y_i)}{\delta X_k} = 2\,[\beta_0\,(\prod_{k=1}^{K} X_k^{\beta_k})]^2\,\frac{\delta[\beta_0(\prod_{k=1}^{K} X_k^{\beta_k})]^2}{\delta X_k}\,Var\,(u_i). \quad (48)$$

Equation (46) is estimated involving three-stage procedure in order to yield asymptotically efficient estimates as outlined in Pope and Just (1977).

Having estimated these equations, the next issue is to compare the optimal input use under the corresponding production functions. For the production risk model with linear mean-variance utility of profit and no price uncertainty, factor demand equations can be derived as follows [see Anderson et al. (1977), Dillon (1977), Just and Pope (1979a), and Hallam et al. (1982)].

$$P\,\frac{\delta E(y)}{\delta X_k} - \phi\,P^2\,\frac{\delta Var(y)}{\delta X_k} = w_k \quad . \qquad (49)$$

For equations (46) through (48), then equation (49) becomes

$$\frac{P\,\alpha_k E(y)}{X_k} - 2\phi\,\frac{\beta_k\,[\beta_0(\prod_{k=1}^{K} X_k^{\beta_k})]^2}{X_k}\,Var\,(u)\,P^2 = w_k\;. \qquad (50)$$

By rearranging (50), factor demand equations would be

$$X_k = \frac{\alpha_k PE(y)}{w_k} - 2\phi\,\frac{\beta_k\,[\beta_0\,(\prod_{k=1}^{K} X_k^{\beta_k})]^2\,P^2}{w_k}\,Var\,(u) + e_k \qquad (51)$$

where w_k is the price of input k, ϕ is risk aversion coefficient (that is, $\phi > 0$ represents risk-aversion, $\phi = 0$ risk-neutrality, and $\phi < 0$

risk preference, respectively) and e_k is the disturbance term such that $E(e_k) = 0$. The complete system of factor demand equation would then be written as:

$$
\begin{aligned}
X_1 &= \theta_{01} + \theta_{11}Z_{11} + \theta_{21}Z_{21} + e_1 \\
X_2 &= \theta_{02} + \theta_{12}Z_{12} + \theta_{22}Z_{22} + e_2 \\
&\vdots \\
X_k &= \theta_{0j} + \theta_{1K}Z_{1K} + \theta_{2K}Z_{2K} + e_K
\end{aligned}
\tag{52}
$$

where

$$Z_{1k} = \frac{aPE(y)}{w_k} \quad \text{and} \quad Z_{2k} = \frac{2bP^2}{w_k}$$

where

$$a = \begin{cases} \hat{\alpha}_k & \text{from C-D production function} \\ \hat{\alpha}_k & \text{from J-P production function} \end{cases}$$

$$b = \begin{cases} \hat{\alpha}_k \, [\alpha_0 \, (\prod_{k=1}^{K} X_k^{\alpha_k})]^2 \text{ Var } (e^{\varepsilon}) & \text{from C-D production function} \\ \hat{\beta}_k \, [\beta_0 \, (\prod_{k=1}^{K} X_k^{\beta_k})]^2 \text{ Var } (u) & \text{from J-P production function} \end{cases}$$

C. Data Set

To implement those two models considered in previous sections, this study utilizes the data collected by Survey Agro Ekonomi (Agro Economic Survey) from its section located in Bogor, Jawa Barat, Indonesia. These data are part of the Rural Dynamic Study in paddy production area of the Cimanuk River Basin, Jawa Barat. The project was originally planned to be continually conducted over years in order to observe farm individual response to economic and social stimulus existing over time in rural community by monitoring current data on labor requirements and employment opportunities, other inputs used in each crop, production costs and prices by crop. Other aspects that were being observed include livestock and machinery ownership and use, land tenure arrangements, consumption pattern, farm and non-farm income sources. However, upon completing two full crop years recording on farm management activities beginning in 1977, the project was unanticipatedly terminated due to lack of funds and changes in administration by the end of 1978. Fortunately, the survey reinstated again in 1983 to the same location and the same farmers.

In 1977, the survey was conducted twice, that is, at the beginning and the end of the year. The first survey was associated with farming practice covering the wet (rainy) season of 1975/1976 and the dry season of 1976. The second survey covered data specifically on household activities in wet season of 1976/1977. In 1978, the visit to the survey area was undergone to cover data on farm management activities at dry season of 1977. The resurvey of 1983 to the same area and same farmers was conducted with a different emphasis on labor requirements and supply, land and asset holding, land tenure arrangements. Not surprisingly, during the five-year period there are tremendous changes prevailing in those aspects. At any rate, some data from farmers could be secured for this study.

The location of the survey is characterized by dominant rice farms, implying having a good water supply and almost similar agroclimate environment. Sample farmers were drawn from six desas by multi stage stratified random sampling from the upper level kecamatans in such a way that those desas should come from six different kecamatans. And these kecamatans were picked randomly from five kabupatens (the higher level administration unit below province). Desa selection was based on four criteria such as: (1) percentage of sawah (rice field) accessible to irrigation water all year round, (2) accessibility to transportation (automotive), (3) proximity to township, and (4) latitude stratum.

From each desa, 60 farmers were selected as respondents representing all farmers in the desa community (Table 8). They were drawn from four strata based on hectareage under their own operated land. The strata are (1) below 0.25 ha, (2) 0.25 to 0.50 ha, (3) 0.50 to 1 ha, and (4) above 1.00 ha. The attempt was to obtain 15 farmers from each stratum. For analyzing farm-level input demands adjusted to seed selection bias, the model is applied against 1977 and 1983 data sets separately based on season and year. But the production under risk model is tested against the same data with conformable individual farmer during the three-year and six-season survey. Ideally, the model would better be estimated from a combination of large cross-section and long time-series of microlevel data on inputs, outputs, and prices. With such a data set, information would be available to estimate not only cross-section production functions, but also to measure directly disturbances affecting price and output as perceived by the farmers. In addition, other information on environmental inputs such as soil organic matter, clay content of soil in farmers' fields, and stochastic inputs such as solar radiation, stress days and other agroclimatic variable in nature would also be desirable. Unfortunately, such a data set is unavailable at this time. So are data on series of yield response experiments on farmers' fields. At any rate, our aim in this study is primarily to ascertain whether both positive and negative marginal risks are likely to exist and to analyze whether this model is better in explaining the input allocation by farmers. We have to assume then that over time the levels of inputs in a given farm are not likely to vary sufficiently to cause a considerable jump in time coefficient.

The variables used are reported and gathered during the six seasons from each farm. They are classified as: (1) observations on gross paddy yield (kg); (2) total expenditure for harvesting yield (kg); (3) net paddy yield (kg); (4) paddy price during harvest season (Rp/kg); (5) value of net paddy yield (Rp); (6) expenditure for buying rice-food (Rp); (7) expenditure for non-rice-food (Rp); (8) total household expenditure (Rp); (9) hectareage of land operated by farmer household (ha); (10) numbers of land fractions; (11) amounts of seed applied (kg) and its value (Rp); (12) amounts and values of fertilizer applied (N, P, and manure) in kg and Rp, respectively; (13) value of pesticide (Rp); (14) total value of production inputs (Rp); (15) seed type dummy, 1 for MV (or HYV) and 0 for TV (or LV); (16) man, woman, and animal labor input used in production process either from family or hired; and (17) age of the head of household (years).

Other additional variables which were documented in the last four

Table 8. Number of rice farms and percentage of irrigated sawah in the area selected for the survey by residency

Residency	Wet season			Dry season			Percentage of irrigated sawah in the desa
	1976	1977	1983	1976	1977	1983	
1. Wargabinangun[a], Gegesik[b], Cirebon[c]	60	60	52	60	60	52	90
2. Lanjan, Lohbener, Indramayu	60	59	53	60	60	53	40
3. Gunungwangi, Argapura, Majalengka	60	60	50	60	60	50	96
4. Malausma, Bantarujeg, Majalengka	60	60	55	60	59	55	33
5. Sukaambit, Situraja, Sumedang	60	60	49	60	60	49	71
6. Ciwangi, Blubur Limbangan, Garut	60	61	53	60	59	53	96
Total	360	360	312	360	358	312	

[a]Desa.

[b]Kecamatan.

[c]Kabupaten.

seasons but not in the first two are: (1) main occupation, (2) dummy for member of government agricultural program BIMAS, (3) tenure, status or tenure arrangements, and (4) non-food expenditure (Rp).

NOTES TO CHAPTER IV

[1]Fixed inputs are considered in the model because if factor inputs are conditional on the level of output and the remaining inputs, then there exists a short-run or variable cost function which is also dual to the production function.

[2]The asymptotic standard errors of parameters of this model are estimated following Lee, Maddala, and Trost (1980).

V. EMPIRICAL RESULTS AND DISCUSSION

The aim of this chapter is to set out the results of the separate independent estimation procedures developed in the two sections of the previous chapter against the data set of 1976, 1977, and 1983 on rice farming activities in both rainy and dry seasons. Further, interpretation and discussion of the individual estimates is also attempted.

Corresponding to the presentation in Chapter IV, the first section of the chapter elaborates the farm-level input demand by applying the sequence of the following estimation approaches: first, probit procedure to analyze factors determining seed selection and to generate an index of the seed selectivity variable; second, systems of cost share functions under the absence of seed selectivity adjustment regime; and third, systems of cost share functions under seed selectivity adjustment. In the second section, the actual estimation of production under risk case will be explained in more detail. Three production specifications, that is, Cobb-Douglas type, Crude model,[6] and Heteroskedastic Model[7] are estimated and their results are also compared. Furthermore, elasticities of output variability with respect to factors of production implied by each model are also evaluated. Lastly, input-use equations implied by the Cobb-Douglas and the Heteroskedastic models are investigated.

A. Farm-level Input Demands

Having adopted the translog cost function as in equation (27) of Chapter IV along with the necessary underlying restrictions as for any typical demand function [equations (27a) and (27b)], we obtain some exogenous variables and some endogenous variables as appeared in Table 9. Then the estimation is proceeded by taking the relationship of endogenous variables on exogenous variables. These constructed variables have no direct economic interpretation but the influence of each of the basic economic variables that constituted the constructed variables as in equation (27) and Table 9 can be derived from the estimation function.

Some descriptive statistics from farmers' samples are summarized in Appendix Tables A1 and A2 for rainy (dry) season data. From the tables it appears that most of quantity variables do not change much between five-year range on data sets in the same season except the net paddy yield means. Of course, there exists quite a change in most price variables supposedly due to an increase in price level from 1977 to 1983. On further analysis, these two-year data sets are treated separately as exemplified in probit estimation results of Table 10. The reason is due to the inability to control for other important changes in conditions between the two periods and to the simplification the the estimation. Also, in this particular section, the data set of 1976 are not included because imputed labor wages, for human and animal, are unreliable.

Since the seed-selection model is derived as the difference in total costs of planting modern and traditional varieties, the restrictions imposed on the total cost function will automatically be carried over to the seed-selection model estimated by the two-stage probit procedure. The estimation results are set out in Table 10.

Table 9. Description of the variables used in the empirical estimation

Name	Description
Endogenous Variables	
LnC^a	{Total expense - Animal labor wage - Insecticide or pesticide expense - (Output*Insecticide or pesticide expense)}
I	Seed type, MV=1 and TV=0
Exogenous Variables	
LnY	Net paddy yield
$LnPM_{sa}$	Seed price - Animal wage
$LnPM_{nfa}$	Nitrogen price - Animal wage
$LnPM_{hla}$	Human labor wage - Animal wage
SPMA1	{(Seed price*Nitrogen price) - (Seed price*Animal wage) - (Nitrogen price*Animal wage) + (Animal wage)^2}
SPMA2	{(Seed price*Human wage) - (Seed price*Animal wage) - (Human wage*Animal wage) + (Animal wage)^2}
SPMB	{(Nitrogen price*Human wage) - (Nitrogen price*Animal wage) - (Human wage*Animal wage) + (Animal wage)^2}
$LYPM_{sa}$	$LnY*LPM_{sa}$
$LYPM_{nfa}$	$LnY*LPM_{nla}$
$LYPM_{hla}$	$LnY*LPM_{hla}$
LHMIP	Landholding - Insecticide or pesticide expense
SPKMA	{(Seed price*Landholding) - (Seed price*Insecticide expense) - (Animal wage*Landholding) + (Animal Wage*Insecticide expense)}

[a]Ln designates natural logarithms.

Table 9. (continued)

Name	Description
SPKMB	{(Nitrogen price*Landholding) - (Nitrogen price*Insecticide expense) - (Animal wage*Landholding) + (Animal wage*Insecticide expense)}
SPKMC	{(Human wage*Landholding) - (Human wage*Insecticide expense) - (Animal wage*Landholding) + (Animal wage*Insecticide expense)}
LYLHMIP	LnY*LHMIP

Table 10. Probit reduced - form coefficient estimates of seed selection equations, 1977 and 1983

Endogenous Variables[a]	Year - 1977		Year - 1983	
	1[b]	2[c]	1[b]	2[c]
Intercept	-6.0612	-2.5108**	4.5001	0.8325
D(.)[d]	-7.5907	-1.5647	-12.9200	-1.4547
LnY	-0.6934	-1.5050	-0.5482	-0.6164
D(.)	0.9830	1.4119	1.5072	0.8903
$1/2(\mathrm{LnY})^2$	0.0567	0.9083	-0.0092	-0.1053
D(.)	-1.1057	-1.1742	0.0334	0.1745
LnPMsa	5.5364	2.22293**	1.8159	0.4437
D(.)	-5.2699	-1.2776	1.9307	0.3055
LnPM_{nfa}	-20.2800	-4.7983***	6.5625	1.2158
D(.)	16.7940	2.2094**	-15.1360	-1.8298*
LnPM^{hla}	5.3271	1.6574*	-6.9973	-1.4927
D(.)	-12.5980	-2.4041**	7.6253	1.2257
$1/2(\mathrm{LnPM}_{sa})^2$	17.7860	5.3744***	6.1705	2.8313***
D(.)	-17.6980	-5.1729***	-2.9788	-1.1296
SPMA1	-16.1580	-5.4421***	-5.0609	-2.2091**
D(.)	15.6010	4.1621***	2.7761	0.8491
SPMA2	7.4380	2.9707***	-0.3103	-0.2078

[a]Complete description of the variables is presented in Table 9.

[b]Coefficients.

[c]Asymptotic t-ratios.

[d]D(.) represents D*Variable right above it, where D=1 for rainy season and D=0 for dry season.

*Significant at $\alpha_{0.10}$=1.695.

**Significant at $\alpha_{0.05}$=1.960.

***Significant at $\alpha_{0.01}$=2.576.

Table 10. (continued)

Endogenous Variables[a]	Year - 1977		Year - 1983	
	1[b]	2[c]	1[b]	2[c]
D(.)	-8.5656	-2.6998***	1.1091	0.5358
$1/2(LnPM_{nfa})^2$	2.6594	1.4900	9.3415	1.0950*
D(.)	6.5741	1.5800	-9.2168	-1.4022
SPMB	-4.7828	-2.0182**	-2.7412	-1.1751
D(.)	0.2180	0.0676	2.7776	0.9371
$1/2(LnPM_{hla})^2$	-0.8789	-0.4483	-0.6639	0.7610
D(.)	0.8709	0.4185	0.7121	0.7386
$LYPM_{sa}$	0.7568	2.3899**	-0.4883	-1.2664
D(.)	-1.2106	-2.5286**	0.2405	0.4182
$LYPM_{nfa}$	0.3834	0.5573	-0.0276	-0.0403
D(.)	0.0821	0.0827	0.7616	0.7956
$LYPM_{hla}$	-1.4043	-2.7742***	0.2111	0.4081
D(.)	1.3701	1.8889*	-0.0541	-0.0717
LHMIP	-0.3228	-0.8723	0.4909	0.8268
D(.)	0.2844	0.5280	-0.0620	-0.0825
$1/2(LHMIP)^2$	0.0658	-1.1104	0.0286	0.3055
D(.)	0.1599	1.6929*	0.1033	0.8238
SPKMA	0.5420	2.5833***	0.0606	0.4751
D(.)	-0.4399	-1.6015	0.0595	-0.3418
SPKMB	-0.0970	-0.2698	0.1680	0.5769
D(.)	0.1335	0.2977	-0.0527	-0.1455
SPKMC	-0.2971	-1.1844	0.1394	0.8401
D(.)	0.1799	0.5625	-0.1201	-0.5044
LYLHMIP	0.0159	0.6252	-0.0014	-0.0400
D(.)	0.0194	0.4778	0.0067	0.1200
Negative Loglikelihood Function	160.65		230.71	
Likelihood Ratio Test	407.74		231.92	
Degrees of Freedom	41		41	
Number of Observations	576		506	

Out of 42 coefficient estimates, 19 (4) are statistically significant for data set of 1977 (1983). Coefficients of first order price variables are mostly significant. So are its season interactions [D(.)] for data of 1977 which are different from those of data of 1983. These coefficient estimates cannot directly show the sign or magnitude of the change in the probability of growing MV rice varieties in response to changes in the exogenous variables. Therefore, we evaluate this sensitivity response in terms of the elasticities as presented in Table 11. One thing that is worth pointing out though, is that these elasticities, like any elasticity coefficient, are very subject to the values where they are evaluated. In this regard, some simplification steps were inevitably made during its calculation. Apart from its direct interpretation, these elasticities will also be used an as adjustment factor in the sample of farmers when calculating total input demand elasticities later in this section.

The results from Table 11 concerning nitrogen fertilizer price are conformable to a priori expectation for all data sets. For instance, it is expected that an increase in fertilizer price, all things remaining the same, will induce a decline in the probability of farmers to use MVs which are shown by coefficients of -2.11 (-0.08) for 1977 rainy (dry) season data and -0.59 (-0.89) for 1983 rainy (dry) season data. On the other hand, the elasticities with respect to seed price, wage rate of human and animal labor have positive signs excluding the elasticities with respect to seed price on rainy season 1977 and the elasticities with respect to human labor wage on dry season 1977. The

Table 11. Estimated elasticities of the probability of choosing MVs evaluated at sample means

Exogenous Variables		Estimated Elasticities	
		1977	1983
Seed price:	RS[a]	-0.05	0.55
	DS[b]	1.26	0.51
Nitrogen price:	RS	-2.11	-0.59
	DS	-0.08	-0.89
Wage rates			
Human labor:	RS	0.22	0.23
	DS	-1.24	0.24
Animal labor:	RS	2.71	0.69
	DS	0.63	0.60
Output level:	RS	-0.06	-0.08
	DS	-0.15	-0.08
Landholding:		-0.02	-0.22
	DS	0.31	-0.06
Insecticide or Pesticide expense:			
	RS	0.02	0.22
	DS	-0.31	0.06

[a]RS designates rainy season.

[b]DS designates dry season.

table also shows that the elasticities with respect to the level of output and landholding are generally negative except that of landholding on dry season data of 1977.

The interpretation of the individual elasticities is generally a relatively straightforward exercise. For example, for all data sets 1977 of rainy and dry seasons, those elasticities illustrate that for a 1 percent increase in nitrogen fertilizer price, all things being equal, there will be a 2.11 (0.08) percent decrease in the probability of growing MVs seed during rainy (dry) season. The magnitude of these elasticities are also as expected; that is, the change in response will be higher during the rainy season than the dry season. Likewise, for 1983 data it appears that for a 1 percent increase in nitrogen price, all things remaining the same, there will be a 0.59 (0.89) percent decrease in the probability of choosing MV seeds during rainy (dry) season. The magnitude of the elasticity on rainy season data is smaller than that of dry season data.

Turning to seed price effect, we would expect that an increase in seed price would cause a decrease in the probability of using MVs. However, this assertion is not supported by the estimated elasticities except for only 1977 rainy season data. This is indeed puzzling. It appears that seed price is not a major factor in determining its adoption. Indeed, the majority of farmers acquire production inputs, especially seed, from government provision channeled through the BIMAS program. These estimates might also be resulted from the fact that seed expense is only a small part of production budget (Appendix

Tables A1 and A2).

With respect to change in wage labor, the signs of the elasticities are generally positive which imply that an increase in human or animal wage rate will tend to raise the probability of planting MVs by rice growers. These results appear to be showing that, given the common knowledge that modern varieties are more labor intensive than local varieties, even though wage rates rise, farmers could still grow modern varieties. This occurs because hired labor, which is subject to market condition, is only a small source of total labor during the rice production process. The effect of a 1 percent increase in output level have all negative signs implying that an increase in the output level will reduce the probability of using MV seeds by 0.06 (0.15) percent on rainy (dry) season data of 1977 and 0.08 percent on both rainy and dry season data of 1983.

Turning to the effect of the size of land operated by rice farm growers, the signs are negative for rainy season of both data sets. For instance, an increase in land size by 1 percent, ceteris paribus, there will be a 0.02 (0.22) percent decline in the probability of planting MVs for 1977 (1983) data. However, during the dry season of 1977 (1983) it appears that for a 1 percent increase in land size operated by a farmer, all things remaining the same, there will be a 0.31 (-0.06) percent change in the probability of planting modern rice varieties. This seems to suggest that the larger the operated land is, the more likely that farmers will avoid planting modern varieties. This appears to contradict the general expectation that larger farmers the more inclined to be receptive adopters. It might have something to do with the aversion to risk on the part of larger farmers. Risk aversion, unfortunately, cannot be simultaneously incorporated in this particular model, due to types and limitations of the data.

Turning back to the total cost function itself, an attempt is made to utilize as much information as is available by estimating it through seemingly unrelated multivariate regression technique developed by Zellner. Specifically, knowing that input share function is derived by taking partial derivative of total cost function with respect to price of particular input, there is a very high probability that the disturbances from each of the included total cost and input share equations are to be correlated because errors in cost minimization which result in overstating on input share will symmetrically affect other input shares. Therefore, greater efficiency in estimation can be achieved by this technique. In addition, iteration of the Zellner's estimation procedure will converge results into maximum likelihood estimates. The results of this iteration of the Zellner's technique are presented in Tables 12 and 13. Note, however, that the estimates for the total cost function are not included due to the fact that by applying Shephard's lemma, everything there is to know about the total cost function is already captured in input share equations.

Estimates on Table 12 are the results from 1977 data and estimates on Table 13 are the results from 1983 data. Incidentally, upper halves of Tables 12 and 13 show the estimates for TVs and bottom halves are the results for MV of 1977 and 1983, respectively.

Turning first to the upper half of Table 12, it shows that only 2

Table 12. Estimated coefficients of input share equations for TVs and MVs without adjustment for seed selectivity bias, 1977

Equations / Exogenous Variables[a]	Share of seed 1[b]	Share of seed 2[c]	Share of nitrogen 1[b]	Share of nitrogen 2[c]	Share of human labor 1[b]	Share of human labor 2[c]
TV Farmers Group						
Intercept	0.0658	1.8565*	0.1601	2.6089***	0.7513	9.4107***
D(.)[d]	0.0480	0.9400	-0.0359	-0.4032	-0.0287	-0.2550
$LnPM_{sa}$	-0.0555	-1.4434	0.0314	0.7979	-0.0356	-1.0273
D(.)	0.0954	2.1146**	-0.0332	-0.6962	0.0042	0.1167
$LnPM_{nfa}$	0.0314	0.7979	0.0486	0.6735	-0.0387	-0.5807
D(.)	-0.0332	-0.6852	-0.0716	-0.8546	-0.0199	-0.2857
$LnPM_{hla}$	-0.0356	-1.0273	-0.0387	-0.5807	0.0926	1.0723
D(.)	0.0042	0.1167	-0.0199	-0.2857	0.0604	0.6770
LnY	-0.0055	-0.9942	0.0211	2.1212**	-0.0139	-1.0861
D(.)	-0.0033	-0.4256	-0.0173	-1.2472	0.0132	0.7397
LHMIP	0.0050	1.2548	-0.0078	-1.1114	0.0089	0.9743
D(.)	-0.0004	-0.0923	0.0181	2.1191**	-0.0088	-0.7946

[a]Complete description of variables is presented in Table 9.

[b]Coefficients.

[c]Asymptotic t-ratios.

[d]D(.) represents D*Variable right above it, where D=1 for rainy season and D=0 for dry season.

*Significant at $\alpha_{0.10}=1.645$.

**Significant at $\alpha_{0.05}=1.960$.

***Significant at $\alpha_{0.01}=2.576$.

Table 12. (continued)

Equations / Exogenous Variables[a]	Share of seed 1[b]	Share of seed 2[c]	Share of nitrogen 1[b]	Share of nitrogen 2[c]	Share of human labor 1[b]	Share of human labor 2[c]
MV Farmers Group						
Intercept	0.0354	1.4239	0.2153	3.0883***	0.6721	8.6304***
D(.)[d]	0.0331	0.8793	0.0219	0.1991	-0.0064	-0.0556
$LnPM_{sa}$	0.0424	3.2395***	-0.0351	-2.1571**	-0.0416	-2.1786**
D(.)	-0.0072	-0.3768	-0.0003	-0.0112	0.0418	1.4626
$LnPM_{nfa}$	-0.0351	-2.1571**	0.0979	1.8466*	-0.0566	-1.0344
D(.)	-0.0003	-0.0112	-0.0782	-0.7721	0.0359	0.3983
$LnPM_{hla}$	-0.0416	-2.1786**	-0.0566	-1.0344	0.1187	1.8397*
D(.)	0.0418	1.4626	0.0359	0.3983	-0.0896	-0.9172
LnY	0.0004	0.1084	0.0151	1.3781	-0.0044	-0.3607
D(.)	-0.0016	-0.3328	-0.0270	-1.7942*	0.0118	0.7069
LHMIP	0.0065	3.6844***	0.0019	0.3526	-0.0044	-0.7267
D(.)	-0.0055	-2.2730**	-0.0125	-1.6456*	0.0173	2.0649**

Table 13. Estimated coefficients of input share equations for TVs and MVs without adjustment for seed selectivity bias, 1983

Equations / Exogenous Variables[a]	Share of seed 1[b]	Share of seed 2[c]	Share of nitrogen 1[b]	Share of nitrogen 2[c]	Share of human labor 1[b]	Share of human labor 2[c]
			TV Farmers Group			
Intercept	0.0575	4.1079***	0.1731	4.3318***	0.8597	14.0460***
D(.)[d]	-0.0316	-1.5925	-0.1149	-2.0147**	-0.0479	-0.5298
$LnPM_{sa}$	0.0057	1.0433	0.0150	2.1881**	-0.0184	-4.7138***
D(.)	0.0016	0.2129	0.0055	0.6051	-0.0148	-2.9536***
$LnPM_{nfa}$	0.0150	2.1881**	0.0884	5.2374***	-0.0596	-5.2803***
D(.)	0.0055	0.6051	0.0033	0.1549	-0.0622	-4.3074***
$LnPM_{hla}$	-0.0184	-4.7138***	-0.0596	-5.2803***	0.0950	4.9907***
D(.)	-0.0148	-2.9536***	-0.0622	-4.3074***	0.0702	2.9528***
LnY	-0.0008	-0.5079	0.0110	2.2362**	-0.0127	-1.5855
D(.)	0.0027	1.0604	0.0048	0.6400	0.0004	0.0293
LHMIP	-0.0005	-0.5509	-0.0077	-0.30801***	0.0192	4.6359***
D(.)	-0.0000	0.0324	-0.0004	-0.1090	-0.0085	-1.5848

[a]Complete description of variables is presented in Table 9.

[b]Coefficients.

[c]Asymptotic t-ratios.

[d]D(.) represents D*Variable right above it, where D=1 for rainy season and D=0 for dry season.

*Significant at $\alpha_{0.10}$=1.645.

**Significant at $\alpha_{0.05}$=1.960.

***Significant at $\alpha_{0.01}$=2.576.

Table 13. (continued)

Equations / Exogenous Variables[a]	Share of seed		Share of nitrogen		Share of human labor	
	1[b]	2[c]	1[b]	2[c]	1[b]	2[c]
			MV Farmers Group			
Intercept	0.0358	1.4661	0.0658	1.5390	0.8701	16.3320***
D(.)[d]	-0.0230	-0.6052	0.1445	2.1952**	-0.1352	-1.5877
$LnPM_{sa}$	0.0810	10.4460***	0.0102	1.0322	-0.0637	-5.7339***
D(.)	-0.0209	-2.0903**	0.0046	0.3510	0.0059	0.3795
$LnPM_{nfa}$	0.0102	1.0322	0.0807	3.3937***	-0.1231	-6.4620***
D(.)	0.0046	0.3510	0.0225	0.6448	0.0218	0.7501
$LnPM_{hla}$	-0.0637	-5.7339***	-0.1231	-6.4620***	0.2047	6.8137***
D(.)	0.0059	0.3795	0.0218	0.7501	-0.0354	-0.8021
LnY	0.0078	2.6238***	0.0137	2.9747***	-0.0247	-3.6881***
D(.)	0.0004	0.0847	-0.0146	-1.9902**	0.0207	1.9209*
LHMIP	-0.0031	-2.9606***	-0.0045	-2.7745***	0.0073	3.1296***
D(.)	-0.0003	-0.2020	-0.0023	-0.9384	-0.0026	-0.7442

out of 12 coefficients are statistically significant on seed share equations, and 3 in nitrogen and 1 in human labor share equations, respectively. On the bottom half of Table 12, we see that 5 out of 12 coefficients are statistically significant on each seed and nitrogen share functions, and 4 in human labor share. For 1983, Table 13 exhibits that 4 out of 12 coefficients are statistically significant on seed share equations, 8 in each nitrogen fertilizer and human labor share functions. The lower half of Table 13 reports that 5 out of 12 coefficients are significant on seed share equations, 6 and 7 on nitrogen and human labor share equations, respectively.

For the purpose of incorporating seed selection as an endogenous decision variable or in other words, to evaluate how important the selectivity variable is, the system of equations in Tables 12 and 13 are reestimated by including the selectivity variable as one of additional exogenous variables as previously outlined in equations (29) and (30) of Chapter IV. In a sense then, this is going to be the two-stage estimation results. The conformable tables to Tables 12 and 13 then are Tables 14 and 15. By observing these tables, out of 12 total input share equations for TVs and MV of 1977 and 1983 data, eight of them have statistically significant selectivity variables as seen on all seed share equations, on nitrogen share equations of MV of 1977 and 1983 data, and on human labor share of 1977 data. This is obviously an evidence of the existence of selection bias in estimating those input share equations from a subsample of farmers. On the other hand, for nitrogen share equations of TVs of 1977 and 1983 data, and human labor share equations of TV 1977 and of 1983 data, seed selection bias appears to be statistically insignificant.

Turning back to Tables 12 and 13, the coefficients again cannot show directly the sign and magnitude of the input elasticity of demand. These elasticities must be derived from mathematical combinations of the coefficients and the value of input share.[2] These derived elasticities appear in Tables 16 to 19 for each data set.

The most obvious feature observed in those tables is that most of the own-price elasticities of demand have correct negative signs on all data sets except on demand for seed and human labor on MV group of dry season 1983 which have positive signs. Also, the elasticity of animal labor wage on animal labor demand function in this data set is positive. The same thing also seems to be true in rainy season data 1983. Moreover, these elasticities also show a tendency to decline, when comparing data sets of 1977 and 1983 in the same season. This phenomenon might be resulted from the fact that over time, farmers also learn their perceived distribution of technical parameters and gather more and more information about adoption. This is illustrated by figures in Appendix Tables A1 and A2 where more farmers are using MVs from 30.16 (35.79) percent of the farmer samples in rainy (dry) season 1977 to 55.08 (57.60) percent in rainy (dry) season 1983.

For the data sets of 1977 and 1983, own-price elasticity of demand for seed are -0.20 (-0.36) and -0.77 (-0.01) for TV (MV) group of rainy season data and -1.48 (-0.43) and -0.82 (0.20) for TV (MV) group of dry season data. It appears that the absolute elasticities of dry season

Table 14. Estimated coefficients of input share equations for TVs and MVs with adjustment for seed selectivity bias, 1977

Equations / Exogenous Variables[a]	Share of seed 1[b]	Share of seed 2[c]	Share of nitrogen 1[b]	Share of nitrogen 2[c]	Share of human labor 1[b]	Share of human labor 2[c]
TV Farmers Group						
Intercept	0.0558	1.6255	0.1585	2.5757**	0.7596	9.5202***
D(.)[d]	0.0638	1.2751	-0.0590	-0.6533	-0.0454	-0.4048
$LnPM_{sa}$	-0.0758	-2.0140**	-0.0132	-0.3324	0.0284	0.7783
D(.)	0.1147	2.5981***	0.0154	0.3201	-0.0568	-1.4955
$LnPM_{nfa}$	-0.0132	-0.3324	0.1021	1.3337	-0.0558	-0.7728
D(.)	0.0154	0.3201	-0.1781	-1.9793**	0.0044	0.0579
$LnPM_{hla}$	0.0284	0.7783	-0.0558	-0.7728	0.0554	0.5967
D(.)	-0.0568	-1.4955	0.0044	0.0579	0.0988	1.0355
LnY	-0.0091	-1.6938*	0.0203	2.0325**	-0.0102	-0.7947
D(.)	0.0001	0.0145	-0.0159	-1.1518	0.0097	0.5452
LHMIP	0.0116	2.9109***	-0.0074	-1.0054	0.0035	0.3691
D(.)	-0.0070	-1.4721	0.0169	1.9167*	-0.0031	-0.2707
SELECT[e]	0.1366	5.7686***	0.0140	0.3134	-0.1186	-2.0761**
D(.)	-0.1202	-3.2554***	-0.1674	-2.4688**	0.2459	2.9907***

[a]Complete description of variables is presented in Table 1.

[b]Coefficients.

[c]Asymptotic t-ratios.

[d]D(.) represents D*Variable right above it, where D=1 for rainy season and D=0 for dry season.

[e]Selectivity variable: $MV=\{f(\phi_i)/F(\phi_i)\}$; and $TV=\{f(\phi_i)/[1-F(\phi_i)]\}$.

*Significant at α0.10=1.645.

**Significant at α0.05=1.960.

***Significant at α0.01=2.576.

Table 14. (continued)

Equations Exogenous Variables[a]	Share of seed		Share of nitrogen		Share of human Labor	
	1[b]	2[c]	1[b]	2[c]	1[b]	2[c]
			MV Farmers Group			
Intercept	0.0202	0.6910	0.1291	1.6779*	0.7451	8.7147**
D(.)[d]	0.0515	1.1477	0.0314	0.1945	-0.0400	-0.2976
$LnPM_{sa}$	0.0502	3.2957***	-0.0319	-1.8611*	-0.0430	-2.2262**
D(.)	-0.0156	-0.7556	-0.0024	-0.0684	0.0434	1.4281
$LnPM_{nfa}$	-0.0319	-1.8611*	0.0813	1.5447	-0.0497	-0.9209
D(.)	-0.0024	-0.0684	-0.1481	-0.9231	0.0756	0.6885
$LnPM_{hla}$	-0.0430	-2.2262**	-0.0497	-0.9209	0.1122	1.7634*
D(.)	0.0434	1.4281	0.0756	0.6885	-0.1089	-1.0616
LnY	0.0017	0.4908	0.0188	1.7312	-0.0080	-0.6662
D(.)	-0.0030	-0.6281	-0.0312	-2.0957**	0.0158	0.9551
LHMIP	0.0056	3.1308***	-0.0018	-0.3315	-0.0008	-0.1350
D(.)	-0.0047	-1.9151*	-0.0089	-1.1694	0.0139	1.6497*
SELECT[e]	-0.0233	-1.7785*	-0.0847	-2.3424**	0.0797	1.9993**
D(.)	0.0274	1.5332	0.0657	1.0974	-0.0744	-1.3251

Table 15. Estimated coefficients of input share equations for TVs and MVs with adjustment for seed selectivity bias, 1983

Equations / Exogenous Variables[a]	Share of seed 1[b]	Share of seed 2[c]	Share of nitrogen 1[b]	Share of nitrogen 2[c]	Share of human labor 1[b]	Share of human labor 2[c]
			TV Farmers Group			
Intercept	0.0419	2.6464***	0.1721	3.7511***	0.9220	12.0290
D(.)[d]	-0.0242	-1.0944	-0.1430	-2.2396***	-0.1404	-1.3239
$LnPM_{sa}$	0.0009	0.1617	0.0255	3.2583***	-0.0228	-5.2650***
D(.)	0.0063	0.7909	-0.0056	-0.5648	-0.0115	-2.1075**
$LnPM_{nfa}$	0.0255	3.2583***	0.0727	3.7983***	-0.0585	-4.4555***
D(.)	-0.0056	-0.5648	0.0186	0.7977	-0.0675	-4.1736***
$LnPM_{hla}$	-0.0228	-5.2650***	-0.0585	-4.4555***	0.1053	4.8968***
D(.)	-0.0115	-2.1075**	-0.0675	-4.1736***	0.0554	2.0807**
LnY	0.0012	0.6498	0.0096	1.7549*	-0.0168	-1.9335*
D(.)	0.0006	0.2278	0.0062	0.7930	0.0042	0.3348
LHMIP	0.0013	1.1433	-0.0084	-2.4572	0.0143	2.5764
D(.)	-0.0005	-0.2659	0.0052	1.0468	0.0002	0.0276
SELECT[e]	0.0158	2.2190**	-0.0068	-0.3246	-0.0428	-1.3048
D(.)	-0.0042	-0.3467	0.0510	1.4830	0.0767	1.3711

[a]Complete description of variables is on Table 9.

[b]Coefficients.

[c]Asymptotic t-ratios.

[d]D(.) designates D* variable right above it, where D=1 for rainy season and D=0 for dry season.

[e]Selectivity variable: $MV=\{f(\phi_i)/F(\phi_i)\}$; and $TV=\{f(\phi_i)/[1-F(\phi_i)]\}$.

*Significant at $\alpha_{0.10}=1.645$.

**Significant at $\alpha_{0.05}=1.960$.

***Significant at $\alpha_{0.01}=2.576$.

Table 15. (continued)

Equations	Share of seed		Share of nitrogen		Share of human labor	
Exogenous Variables[a]	1[b]	2[c]	1[b]	2[c]	1[b]	2[c]
			MV Farmers Group			
Intercept	0.0287	1.0916	0.1094	2.4036**	0.8597	15.652***
D(.)[d]	-0.0090	-0.2220	0.1239	1.7575*	-0.0932	-1.0486
$LnPM_{sa}$	0.0696	7.3025***	0.0038	0.3131	-0.0693	-5.9605***
D(.)	-0.0204	-1.7088*	0.0134	0.8414	-0.0016	-0.1003
LPM_{nfa}	0.0038	0.3131	0.0944	3.6924***	-0.1225	-6.3468***
D(.)	0.0134	0.8414	0.0059	0.1597	0.0274	0.9173
$LnPM_{hla}$	-0.0693	-5.9605***	-0.1225	-6.3468***	0.2009	6.7088***
D(.)	-0.0016	-0.1003	0.0274	0.9173	-0.0432	-0.9765
LnY	0.0086	2.9033***	0.0157	3.3383***	-0.0247	-3.6663***
D(.)	0.0017	0.3547	-0.0165	-2.2220**	0.0232	2.1408**
LHMIP	0.0008	0.4933	-0.0004	-0.1556	0.0073	2.1425**
D(.)	0.0012	0.0428	-0.0043	-1.0941	0.0051	0.9000
SELECT[e]	0.0382	2.7636***	0.0479	2.3169**	-0.0009	-0.0325
D(.)	0.0068	0.3408	-0.0304	-0.9842	0.0668	1.6119

Table 16. Estimated elasticities of input demands evaluated at sample means, rainy season 1977

Exogenous Variables		Demand for Seed	Nitrogen	Human Labor	Animal Labor
Seed price	TV	-0.20	0.02	-0.53	-0.07
	MV	-0.36	-0.52	0.06	0.06
Nitrogen price	TV	0.23	-0.86	-0.02	0.59
	MV	0.13	-0.66	0.19	0.19
Wage rates Human labor	TV	0.56	0.52	-0.14	0.51
	MV	0.66	0.63	-0.30	0.65
Animal labor	TV	1.38	0.95	-4.65	-1.04
	MV	0.01	2.45	-0.56	-2.84
Output level	TV	-2.00	-1.82	-1.83	-1.92
	MV	-4.16	-4.19	-4.17	-2.18
Landholding	TV	6.81	6.77	6.73	6.58
	MV	6.91	6.86	6.92	6.67
Insecticide or Pesticide expense	TV	6.64	6.68	6.73	6.88
	MV	6.88	6.94	6.88	7.12

Table 17. Estimated elasticities of input demands evaluated at sample means, dry season 1977

Exogenous Variables		Demand for Seed	Nitrogen	Human Labor	Animal Labor
Seed price	TV	-1.48	0.42	-0.26	0.72
	MV	-0.43	-0.32	-0.39	0.48
Nitrogen price	TV	0.37	-0.56	0.08	0.07
	MV	0.17	-0.37	0.09	0.27
Wage rates Human labor	TV	0.57	0.57	-0.22	0.60
	MV	0.53	0.50	-0.20	0.56
Animal labor	TV	1.95	-1.30	-0.56	-0.97
	MV	1.22	-0.19	-0.68	-1.24
Output level	TV	-1.86	-1.71	-1.82	-1.86
	MV	-2.38	-2.12	-1.83	-2.78
Landholding	TV	6.05	5.97	5.98	5.81
	MV	6.74	6.67	6.66	6.52
Insecticide or Pesticide expense	TV	5.95	6.03	6.02	6.20
	MV	6.59	6.66	6.67	6.80

Table 18. Estimated elasticities of input demands evaluated at sample means, rainy season 1983

Exogenous Variables		Demand for			
		Seed	Nitrogen	Human Labor	Animal Labor
Seed price	TV	-0.77	0.57	-0.83	0.18
	MV	-0.01	0.29	-0.83	2.07
Nitrogen price	TV	0.21	-0.23	-0.68	0.21
	MV	0.25	-0.17	-0.51	0.01
Wage rates					
Human labor	TV	0.71	0.59	-0.03	0.74
	MV	0.65	0.59	-0.04	0.74
Animal labor	TV	0.15	0.22	-0.11	1.23
	MV	-0.25	-0.25	-0.13	-0.15
Output level	TV	-2.30	-2.24	-2.36	-2.44
	MV	-3.16	-3.30	-3.30	-3.35
Landholding	TV	6.81	6.28	6.82	6.77
	MV	8.18	8.19	8.24	8.34
Insecticide or Pesticide expense	TV	6.81	7.33	6.79	6.84
	MV	8.29	8.28	8.23	8.14

Table 19. Estimated elasticities of input demands evaluated at sample means, dry season 1983

Exogenous Variables		Demand for			
		Seed	Nitrogen	Human Labor	Animal Labor
Seed price	TV	-0.82	0.39	-0.39	-0.48
	MV	0.20	0.21	-0.82	0.01
Nitrogen price	TV	0.25	-0.26	-0.25	-0.14
	MV	0.23	-0.35	-0.56	0.31
Wage rates Human labor	TV	0.75	0.69	-0.11	0.75
	MV	0.63	0.55	0.00	0.70
Animal labor	TV	-0.03	-1.16	-0.43	0.76
	MV	-0.62	0.82	-0.39	-0.64
Output level	TV	-2.14	-2.05	-2.13	-2.05
	MV	-2.65	-2.68	-2.79	-2.68
Landholding	TV	6.43	5.93	6.47	6.14
	MV	7.58	7.60	7.63	7.70
Insecticide or Pesticide expense	TV	6.46	6.98	6.42	6.75
	MV	7.67	7.65	7.61	7.55

data are higher than that of the rainy season data which somewhat suggests that the farmers are more responsive to price change of seed during the dry season. Comparison of elasticities between groups, TV and MV farmers are quite mixed. In 1977 rainy season data the absolute elasticity of demand for seed by TV group is less than that of by MV group but for dry season data it is the reverse. So it appears that a 1 percent increase in seed price, ceteris paribus, will cause a reduction in demand for seed by 0.20 (0.36) and 0.77 (0.01) percent during rainy season of 1977 (1983). And for dry season of 1977 and increase in seed price by 1 percent, other things remaining the same, will cause 1.48 (0.43) percent reduction in demand for seed by TV (MV) group. However, for dry season of 1983, an increase in seed price by 1 percent, keeping everything constant, there will be a decrease in demand for seed by TV group by -0.82 percent and an increase by MV group by 0.20 percent.

Comparing to Sumodiningrat's (1982) study, this result has a wider range assuming that positive elasticities such as 0.20 percent are ruled out. He found on his data set of rice farmers in Jawa-Bali in the period of 1979-80 that seed price elasticities of demand was -0.14 (-0.58) for TV (MV) rice farmers group.

Regarding the own-price elasticities of demand for nitrogen fertilizer, surprisingly enough, TV farmers group have a higher value in all data sets except in dry season of 1983. The values are -0.86 (-0.66) and -0.23 (-0.17) for rainy season data of 1977 and 1983 of TV (MV) group and -0.56 (-0.37) and -0.26 (-0.35) for dry season data of 1977 and 1983 of TV (MV) group. This says, then, that in rainy season data of

1977 and 1983, a 1 percent increase in nitrogen fertilizer price, ceteris paribus, will tend to decrease demand for fertilizer by 0.86 (0.66) percent and 0.23 (0.17) percent in TV (MV) group, given that everything else remains the same. It then suggests that traditional variety rice farmers are relatively more sensitive to change in fertilizer price than modern variety rice farmers. This might be true if we assume on one hand, that most MV farmers were members of BIMAS program and on the other hand, that most TV farmers were not. Hence, while MV farmers could attain their fertilizer need through the BIMAS package, TV farmers could only acquire the fertilizer from the local market. Based on Philippines data in 1975, Barker and Anden (1975) found that the fertilizer demand elasticity was about -0.50 and Pitt[3], in his study of the 1973 agricultural census data, found elasticity was -0.50 in Java rice farmers. Sumodiningrat's result was -0.47 (-0.42) for TV (MV) rice farmers group.

With respect to the own-price elasticity of demand for human labor, TV farmers have no different elasticities with that of MV farmers group which is in the neighborhood of -0.30 to 0.00. In contrast with the demand for animal labor, the absolute own-price elasticities are higher in MV group for data of 1977. The opposite is true for data of 1983, where the own-price elasticities of labor of TV group is higher than that of MV group. Note that, the elasticities are positive for TV group and negative for MV group. These results are quite different with Sumodiningrat's results. He found that TV rice farmers had a higher animal labor elasticity of demand than MV group. One conjecture that there seems to be true on 1977 data is that MV farmers do not rely much on animal labor for certain farm chores as opposed to TV farmers. Hence, any percentage change in animal wage rate will induce MV farmers to make more percentage change in demand for animal labor.

Tables 16 to 19 also show that for any percentage increase in output level, ceteris paribus, there will be a decline in demand for all inputs in all data sets. It appears that the absolute value of elasticities are always higher in the MV group than the TV group. Furthermore, regarding the elasticities with respect to landholding, it also appears that the values for the MV group are always higher than the TV group. In Tables 16 to 19, it can also be observed the estimates of the cross-price elasticities among input, that is, a percentage change in demand for particular input due to a percentage change in other input prices and the degree of substitutability, is measured by the coefficient of elasticities of substitution [4] (Tables A3 and A4). The sign of cross-price elasticities is mixed, either within a particular data set or among particular data sets. However, four remarks can be summarized from the tables that: 1) signs of cross-price elasticities of demand for seed with respect to nitrogen fertilizer price or wage rate of human labor are always positive which appears to be suggesting that for any price increase in fertilizer price or wage rate, everything else is equal, there will be an increase in demand for seed, 2) cross-price elasticities of demand for nitrogen fertilizer with respect to wage rate of human labor are always positive, 3) cross-price elasticities of demand for human labor with respect to animal labor are always negative, and 4) cross-price elasticities of demand for animal labor with respect to human labor are always positive. This is a bit puzzling. It appears to be indicating, on one hand, a direction of complementary rather than substitutability of human labor and animal labor. In this sense, it confirms the hypothesis that human labor and animal labor each performs specialized and diverse activities that cannot be interchanged. On the other hand, for an increase in wage rate of human labor there will be an increase in demand for animal labor.

Another very important aspect of this study is the issue of adjusting seed selectivity bias on the elasticity estimates already summarized in Tables 16 and 19. Based on those results, total elasticities of demand for a particular input can be calculated for a typical farmer sample.

The expected demand for an input by a representative farmer having mean endowments of fixed inputs and facing mean prices is (Pitt, 1983)

$$E(Q_k) = E(Q_k \mid I=1)\ \mathrm{Prob}(I=1) + E(Q_k \mid I=0)\ \mathrm{Prob}(I=0)$$

where $E(Q_k \mid I=1)$ and $E(Q_k \mid I=0)$ are the demand for input Q_k under a MV and TV seed regime, respectively; and Prob(I=1) and Prob(I=0) are the probabilities of observing an MV and a TV farmer, respectively. Hence, the total price elasticity of demand (ε) can be written as

$$\varepsilon = \frac{\varepsilon_m\ E(Q_k \mid I=1)\ \mathrm{Prob}(I=1)}{E(Q_k)} + \frac{\varepsilon_t\ E(Q_k \mid I=0)\ \mathrm{Prob}(I=0)}{E(Q_k)}$$

$$+ \delta \frac{E(Q_k|I=1) - E(Q_k|I=0)}{E(Q_k)} \quad \text{Prob}(I=1)$$

where δ is the elasticity of the probability of choosing MV seeds with respect to any exogenous variables (see Table 11) and ε_m and ε_t are input demand elasticities with respect to any exogenous variables as shown in Tables 16 to 19. The total price elasticities of demand for an input are illustrated in Tables 20 and 21[5]. Columns 1 (3) of Tables 12 and 13 indicate the total elasticities of rainy (dry) season data without selectivity bias adjustment and columns 2 (4) indicate the total elasticities of rainy (dry) season data with selectivity bias adjustment in the sense that these elasticities are adjusted for the change in the probability of choosing MV as a result of an input price increase.

From observation of Tables 20 and 21, the inclusion of elasticities of the probability of planting MV due to a price increase has very mixed results. In some instances, it reinforces the elasticities calculated from the case without adjustment, such as own-price elasticities of demand for seed and animal labor in dry season 1977 and own-price elasticities of demand for human and animal labor in rainy season 1977. This also holds true in the own-price elasticity of demand for nitrogen fertilizer in rainy and dry season 1983. For other cases, the elasticities of the probability of choosing MV helps to mitigate the total elasticities of demand as illustrated by the own-price elasticities of demand for nitrogen fertilizer of rainy season data 1977 and human labor in the data of 1983 during rainy and dry season. Moreover, the total elasticities of demand also show a tendency

Table 20. Total elasticities of demand for input, 1977

Demand for: with respect to price or wage	Elasticities of demand for input			
	Rainy season		Dry Season	
	1[a]	2[b]	1[a]	2[b]
Seed:				
Seed	-0.28	-0.28	-1.02	-1.07
Fertilizer	0.18	0.18	0.28	0.29
Human labor	0.61	0.61	0.55	0.61
Animal labor	0.70	0.69	1.63	1.60
Fertilizer:				
Seed	-0.22	-0.22	0.08	0.04
Fertilizer	-0.77	-0.70	-0.47	-0.47
Human labor	0.57	0.56	0.54	0.57
Animal labor	1.62	1.53	-0.79	-0.80
Human labor:				
Seed	-0.28	-0.28	-0.31	-0.41
Fertilizer	0.07	0.17	0.08	0.09
Human labor	-0.21	-0.22	-0.21	-0.11
Animal labor	-2.95	-3.08	-0.61	-0.66
Animal labor:				
Seed	-0.06	-0.05	0.67	0.40
Fertilizer	0.57	1.12	0.11	0.13
Human labor	0.52	0.46	0.59	0.86
Animal labor	-1.15	-1.87	-1.02	-1.16

[a]Without seed selectivity bias adjustment.

[b]With seed selectivity bias adjustment.

Table 21. Total elasticities of demand for input, 1983

Demand for: with respect to price or wage	Elasticities of demand for input			
	Rainy season		Dry Season	
	1[a]	2[b]	1[a]	2[b]
Seed:				
Seed	-0.24	-0.18	-0.16	-0.07
Fertilizer	0.24	0.11	0.24	0.08
Human labor	0.67	0.72	0.67	0.71
Animal labor	-0.13	0.02	-0.41	-0.31
Fertilizer:				
Seed	0.39	0.48	0.28	0.34
Fertilizer	-0.19	-0.29	-0.31	-0.42
Human labor	0.59	0.63	0.61	0.63
Animal labor	-0.09	0.03	0.04	0.11
Human labor:				
Seed	-0.83	-0.77	-0.62	-0.60
Fertilizer	-0.58	-0.69	-0.41	-0.44
Human labor	-0.04	-0.01	-0.05	-0.04
Animal labor	-0.12	-0.05	-0.41	-0.39
Animal labor:				
Seed	1.30	1.36	-0.22	-0.20
Fertilizer	0.09	0.03	0.10	0.06
Human labor	0.74	0.76	0.72	0.73
Animal labor	0.41	0.48	0.01	0.03

[a]Without seed selectivity bias adjustment.

[b]With seed selectivity bias adjustment.

to wane over time at the same season.

To sum up this section, two-stage probit procedure is applied to accommodate the possibility of incorporating seed selection as an endogenous variable decision which is hypothesized to be a function of exactly the same endogenous variables that affect the total cost function. It is found that the elasticities of the probability of planting MVs with respect to seed price is -0.05 (1.26) during rainy (dry) season 1977 and 0.55 (0.51) during rainy (dry) season 1983. With respect to nitrogen fertilizer price, then elasticities are -2.11 (-0.08) for rainy (dry) season 1977 and -0.59 (-0.89) for rainy (dry) season 1983. For the operated land, the elasticities are 0.02 (0.22) from 1977 (1983) rainy season data and 0.31 (-0.06) from 1977 (1983) dry season data.

Own-price elasticities of input demands have the appropriate signs on each data set and for each farmer group. Cross-price elasticities of input demand have mixed signs. Total own-price elasticities of demand for seed with seed selectivity bias adjustment are -0.28 (-1.07) for rainy (dry) season 1977 and -0.11 (-0.07) for rainy (dry) season 1983. In the case of no seed selectivity bias adjustment, the elasticities are -0.28 (-1.02) for rainy (dry) season 1977 and -0.24 (-0.16) for rainy (dry) season 1983. So, for 1983 data, there is correction downward with bias adjustment. Total elasticities of demand for nitrogen fertilizer are -0.70 (-0.47) for rainy (dry) season 1977 and -0.29 (-0.42) for rainy (dry) season 1983 under selectivity bias adjustment. In no selectivity bias adjustment case, the elasticities are -0.77 (-0.47) for rainy (dry) season 1977 and -0.19 (-0.31) for rainy (dry) season 1983. Hence, it appears that there is a downward correction for 1977 data and upward correction of 1983 data due to the adjustment. Incidentally, in his analysis of wet rice farming in Java, 1971, Pitt (1983) found the total elasticity of demand with respect to fertilizer price was -1.155 and -1.042 under seed switching adjustment and no adjustment, respectively. Meanwhile, Sumodiningrat's (1982) results for 1979-80 period are -0.47 and -0.35, respectively.

Finally, it also appears that total own-price elasticities of demand show a tendency to wane over time.

B. Production under Risk

Application of analytical framework set out in the last section of Chapter III and further refined in Section B of Chapter IV is performed here. The data sets are composed of observations that exist in three cross-section years, that is, in 1977, 1978, and 1983. The summary statistics are shown in Table 22.

The first step in our estimation is by applying Cobb-Douglas production function through its loglinear transformation. The model is estimated by OLS and results of the estimation are summarized in Table 23. All of the factors of production coefficients are statistically significant in both data sets, rainy and dry season, except animal labor and insecticide or pesticide expense. All coefficients have the expected positive signs with the exception of insecticide expense. We anticipate that for any percentage increase in a factor of production, ceteris paribus, there will be a percentage increase in yield. With

Table 22. Means of selected variables

Variables	Rainy Season	Dry Season
Net paddy yield (kg)	1326.7	962.90
Seed (kg)	19.67	16.65
Nitrogen fertilizer (kg)	104.79	80.88
Phosphorous fertilizer (kg)	37.93	28.93
Human labor (mandays)	366.50	247.03
Animal labor (animaldays)	9.94	3.92
Landholding (ha)	0.48	0.37
Insecticide or pesticide expense (Rp)	567.48	315.82
Number of observations	226x3=678	185x3=555

respect to insecticide or pesticide expense of rainy season data, the sign is negative but is relatively very small and not statistically significant. The insignificance of animal labor and insecticide or pesticide expense in production function is probably dictated by the uncommon application of the factor in the sample farmers. Most of the farmers use human labor as source of labor be it either as coming from the family or hired from outside if he could afford to. Only a few farmers applied insecticide or pesticide. They usually are relatively large farmers (more than 0.50 ha landholding).

The second alternative specification attempted in the analysis is by applying a 'crude' model analogous to Anderson's (1973).[6] The results of mean production are given in Table 24. The coefficient

Table 23. Estimated coefficients of Cobb Douglas production function, rainy and dry season

Factor of Production	Coefficients	
	Rainy Season	Dry Season
Intercept	6.5547 (21.3640)***	4.5068 (19.3490)***
Seed	0.0751 (2.0049)**	0.4584 (8.6724)***
Nitrogen fertilizer	0.0433 (2.1424)**	0.0588 (2.6049)***
Phosphorous fertilizer	0.0569 (5.5118)***	0.0206 (1.8211)*
Human labor	0.0824 (2.0828)**	0.1788 (5.5896)***
Animal labor	0.0087 (1.2817)	0.0088 (0.8983)
Landholding	0.6818 (11.3700)***	0.2580 (5.9071)***
Insecticide or pesticide expense	-0.0073 (-0.7218)	0.0103 (0.7297)

[a] Numbers in parentheses are respective t-ratios.

*Significant at $\alpha_{0.10} = 1.645$.

** Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.

Table 24. Estimated coefficients of mean production for Crude model

Factor of production	Mean production	
	Rainy Season	Dry Season
Intercept	5.2273 (14.0600)***	4.4380 (8.8490)***
Seed	0.2240 (3.7090)***	0.0489 (0.7680)
Nitrogen fertilizer	0.2795 (5.4800)***	0.3546 (5.3170)***
Phosphorous fertilizer	0.0636 (3.1970)***	0.0108 (0.6470)
Human labor	0.0235 (0.4870)	0.2141 (3.2480)***
Animal labor	0.0113 (3.0520)***	0.0103 (1.7510)*
Landholding	0.4271 (6.1350)***	0.4678 (5.5560)***
Insecticide or pesticide expense	-0.0094 (-1.5670)	0.0011 (0.1190)

estimate are quite similar to the results in Table 23. Most coefficients are statistically significant except human labor and insecticide expense in rainy season data and seed, phosphorous fertilizer, and insecticide expense in dry season data. Again in the model, the estimate of insecticide coefficient is negative for rainy season data.

The last specification estimated is the Heteroskedastic model of Just and Pope type (1978, 1979a,b)[7] as outlined in equations (46) through (48) of Chapter IV. The estimates of mean production are summarized in Table 25. Comparing with the results from the previous two alternatives, the estimates are quite different. For rainy season data, all estimates are statistically (and asymptotically) significant with the exception of nitrogen fertilizer coefficient. In dry season data, all coefficients are statistically significant with the exception of insecticide expense which also has a negative sign. By using this procedure, it is very surprising to see that elasticity of mean production with respect to nitrogen fertilizer is statistically not significant which is contrary to that shown by the first two models. This might have happened because the effect of nitrogen fertilizer on production might be confounded by other inputs, because inputs other than labor and land are obtained from the package of BIMAS in fixed proportions. To substantiate this assertion, simple correlation coefficients among inputs are computed in the Appendix Table A5. As we can see from the table, simple correlations of nitrogen fertilizer with seed, phosphorous fertilizer, and insecticide are all significant in

Table 25. Estimated coefficients of mean production for Heteroskedastic model

Factor of Production	Mean Production			
	Rainy Season		Dry Season	
	First stage[a]	Final stage	First stage	Final stage
Intercept	1221.3 (4.2171)***	832.70 (816.9200)***	633.44 (3.7835)***	693.86 (182.98)***
Seed	0.0827 (1.7694)*	0.1301 (3.0915)***	0.1068 (3.8476)***	0.1136 (3.4654)***
Nitrogen fertilizer	-0.0080 (-1.6096)	0.0025 (0.3279)	0.0140 (0.5057)	0.0319 (2.0684)**
Phosphorous fertilizer	0.0409 (6.8227)***	0.0434 (6.3006)***	0.0139 (2.2415)**	0.0212 (3.6099)***
Human labor	0.0711 (2.4395)**	0.0899 (3.8735)***	0.1761 (4.5114)***	0.1276 (6.0639)***
Animal labor	0.0254 (8.8131)***	0.0143 (4.7252)***	0.0413 (9.9878)***	0.0267 (6.1854)***
Landholding	0.8290 (15.3090)***	0.7366 (27.7500)**	0.6759 (14.072)***	0.6809 (24.6230)***
Insecticide or pesticide expense	0.0091 (1.7982)*	0.0112 (2.4960)**	-0.0212 (-4.1398***)	-0.0091 (-1.4305)

[a]Numbers in parentheses are respective asymptotic t-ratios.

* Significant at $\alpha_{0.10} = 1.645$.

** Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.

both rainy and dry season data.

Furthermore, Table 25 also shows that in the dry season data, the sign for insecticide expense is negative which is also contrary to the previous results. One possible explanation has something to do with the improper application of insecticide or pesticide in terms of technique or timing.

Specific to the Cobb-Douglas production type, these estimates are also designating the elasticities of mean production with respect to the corresponding factor of production. By using our nonlinear or heteroskedastic estimation results, a 1 percent increase in each factor of production of seed, nitrogen fertilizer, phosphorous fertilizer, human labor, animal labor, landholding, and insecticide or pesticide expense, respectively, other things remaining constant, will cause a 0.13, 0.00, 0.04, 0.09, 0.01, 0.74, and 0.01 percent increase in yield in rainy season data and 0.11, 0.03, 0.02, 0.13, 0.03, 0.68 percent increase and -0.01 percent decrease in yield for dry season data.

The next important aspect that needs to be considered is the relationship between the level of inputs and the variance of production as can be deduced from the Crude model and the Heteroskedastic model. We hypothesize that the coefficients associated with human and animal labor, and insecticide and pesticide expense, to have a risk-reducing effect on the variance of the production.

The amount of labor spent during the production process is considered to make production yield more stable to a certain level, especially if it is given at the right time. The same argument holds for insecticide and pesticide expense. A rice grower is willing to spend additional money to buy insecticide or pesticide in the expectation that production yield level becomes more certain than it otherwise would have been. Again, this assumption will be true if the timing for application of insecticide and pesticide is right during the cultivation.

For seed, nitrogen fertilizer, phosphorous fertilizer, and landholding, the coefficients are expected to be positive indicating the risk-inducing effects. As pointed out in Chapter III, these inputs are thought to be making production yield more susceptible to environmental condition.

Table 26 shows the coefficient estimates for the Crude model and Table 27 for the Heteroskedastic model. By observing Table 26, we see that 4 out of 8 coefficients are statistically significant for rainy season data and 3 out of 8 coefficients in dry season.

Out of 8, three (one) have negative signs in rainy (dry) season data. In rainy season data they are nitrogen fertilizer, human labor, and animal labor and for dry season data it is seed quantity. These results are somewhat contrary to the expectation, namely that human labor, animal labor, and insecticide expense will behave as risk-reducing factors as opposed to risk-inducing of the rest of factor productions. Despite the correct signs shown by human and animal labor input, insecticide expense fails to do so for rainy season data. In dry season data, the signs for human and animal labor, and insecticide expense are in conflict with the expectation.

Turning to Table 27 as for results on Heteroskedastic model, there are some similarities between these results and those of Table 26, even though the extent of statistical significance in individual effects is different. In addition, Table 27 shows that nitrogen fertilizer picks up the correct negative sign showing a risk-inducing factor in rainy season data but again fails to show risk-reducing effects of insecticide or pesticide expense in both data sets, and of human and animal labor in dry season data.

Since the estimated functions of variance of production for Crude model is linear in parameters (Table 26), the coefficients can be interpreted as risk elasticities. Therefore, a 1 percent increase in the use of seed results in a 1.31 (−0.12) percent increase (decrease) in the variance of production in rainy (dry) season data, everything else is the same. Similar interpretation can be applied to all other estimates.

With respect to Cobb-Douglas and Heteroskedastic models, these elasticities are calculated in Tables 28 and 29, respectively.[8] The estimated elasticities of Cobb-Douglas and Heteroskedastic model are very close to one another but they are derived from different mean production functions. The signs of elasticities in Cobb-Douglas functions are already determined in the mean production functions unintentionally while the signs of elasticities in Heteroskedastic model are free from the results of the mean production functions due to the fact that the mean and the variance functions are allowed to be independent of one another. In other words, we could still have an

Table 26. Estimated coefficients of variance of production for Crude model

	Variance of production	
Factor of Production	Rainy Season	Dry Season
Intercept	10.6103 (5.8460)***	10.0038 (5.5290)***
Seed	1.3111 (4.4470)***	-0.1238 (-0.5390)
Nitrogen fertilizer	-0.1237 (-0.4970)	0.5179 (2.1520)**
Phosphorous fertilizer	0.1595 (1.6420)	0.0733 (1.2160)
Human labor	-0.2262 (-0.9590)	0.2211 (0.9300)
Animal labor	-0.0280 (-1.5430)	0.0307 (1.4470)
Landholding	0.9006 (2.6500)**	1.1506 (3.7890)***
Insecticide or pesticide expense	0.0640 (2.1940)**	0.0315 (0.9510)

[a]Numbers in parentheses are respective asymptotic t-ratios.

* Significant at $\alpha_{0.10} = 1.645$.

** Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.

Table 27. Estimated coefficients of variance of production for Heteroskedastic model

Factor of Production	Variance of Production[a] Rainy Season	Dry Season
Intercept	13.376 (14.2370)***	7.6310 (12.207)***
Seed	0.0558 (0.9726)	0.4045 (5.7021)***
Nitrogen fertilizer	0.0167 (0.5403)	0.0662 (2.1870)**
Phosphorous fertilizer	0.0017 (0.1062)	0.0272 (1.7940)
Human labor	-0.1423 (-2.3497)**	0.0817 (1.9041)
Animal labor	-0.0137 (-1.3168)	0.0186 (1.4157)
Landholding	0.9396 (10.2340)***	0.2108 (3.5975)***
Insecticide or pesticide expense	0.0341 (2.1890)**	0.0115 (0.6046)

[a]Numbers in parentheses are respective asymptotic t-ratios.

* Significant at $\alpha_{0.10} = 1.645$.

** Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.

Table 28. Estimated elasticities of output variability with respect to factor of production implied by Cobb-Douglas model evaluated at means

Factor of Production	Elasticities	
	Rainy Season	Dry Season
Seed	0.15	0.92
Nitrogen fertilizer	0.09	0.12
Phosphorous fertilizer	0.11	0.04
Human labor	0.16	0.36
Animal labor	0.02	0.02
Landholding	1.36	0.52
Insecticide or pesticide expense	0.01	0.02

Table 29. Estimated elasticities of output variability with respect to factor of production implied by Heteroskedastic model evaluated at means

	Elasticities	
Factor of Production	Rainy Season	Dry Season
Seed	0.11	0.81
Nitrogen fertilizer	0.03	0.13
Phosphorous fertilizer	0.00	0.05
Human labor	-0.28	0.16
Animal labor	-0.03	0.37
Landholding	1.88	0.42
Insecticide or pesticide expense	0.07	0.02

input having positive marginal product but negative marginal risk. This is one of the advantages of using Heteroskedastic model as outlined in Chapter IV.

Turning to the results from Table 29 of Heteroskedastic model, a 1 percent increase in the use of seed results in a 0.11 (0.81) increase in the variance of the production in rainy (dry) season data, everything held constant. And 1 percent increase in the use of nitrogen fertilizer, ceteris paribus, results in 0.03 (0.13) percent increase in the variance of production of rainy (dry) season data. The same thing can be applied to other remaining estimated elasticities.

One last issue that we are going to take up before closing this section is about the implication of estimated production models on the

Table 30. Estimated coefficients of implied input-use equations for Cobb-Douglas and Heteroskedastic models, rainy season[a]

Parameters/ Statistics	Cobb-Douglas Model			
	Risk-responsive		Risk-neutral	
	Nitrogen[b]	Labor	Nitrogen	Labor
θ_{0i}	18.295 (3.4862)***	269.360 (16.4620)***	31.297 (6.9940)***	300.99 (14.3670)***
θ_{1i}	1.4900 (17.6960)***	-0.1375 (-2.4876)	1.1525 (29.435)***	0.5610 (11.5560)***
θ_{2i}	0.2071×10^{-6} (4.5023)	-0.1768×10^{-5} (-17.265)***		
R^2	0.67	0.53	0.66	0.23
F	461.900	259.892	866.425	133.552

[a]Only two major inputs, that is, nitrogen and labor, are considered.

[b]Numbers in parentheses are respective t-ratios.

*Significant at $\alpha_{0.10} = 1.645$.

**Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.

Table 30. (continued)

Parameters/ Statistics	Heteroskedastic Model			
	Risk-responsive		Risk-neutral	
	Nitrogen	Labor	Nitrogen	Labor
θ_{0i}	30.935 (5.8588)***	238.47 (13.669)***	31.297 (6.9940)***	300.99 (14.367)***
θ_{1i}	20.1130 (13.3040)***	0.2570 (6.4689)***	19.938 (29.4350)***	0.5132 (11.5567)***
θ_{2i}	0.6184×10^{-12} (0.1293)	0.3049×10^{-10} (15.397)***		
R^2	0.66	0.49	0.66	0.23
F	432.274	220.350	866.425	133.552

Table 31. Estimated coefficients of implied input-use equations for Cobb-Douglas and Heteroskedastic models, dry season[a]

Parameters/ Statistics	Cobb-Douglas Model			
	Risk-responsive		Risk-neutral	
	Nitrogen[b]	Labor	Nitrogen	Labor
θ_{0i}	14.758 (3.0637)***	114.840 (10.863)***	22.828 (5.5312)***	102.460 (9.7182)***
θ_{1i}	0.9654 (14.977)***	0.5908 (11.6580)***	0.7875 (25.1050)***	0.7752 (23.0770)***
θ_{2i}	0.7974×10^{-7} (3.1474)***	-0.1431×10^{-6} (-4.7550)***		
R^2	0.64	0.61	0.63	0.59
F	327.720	293.220	630.280	532.556

[a]Only two major inputs, that is, nitrogen and labor, are considered.

[b]Numbers in parentheses are respective t-ratios.

*Significant at $\alpha_{0.10}$ = 1.645.

**Significant at $\alpha_{0.05}$ = 1.960.

***Significant at $\alpha_{0.01}$ = 2.576.

Table 31. (continued)

Parameters/ Statistics	Heteroskedastic Model			
	Risk-responsive		Risk-neutral	
	Nitrogen	Labor	Nitrogen	Labor
θ_{0i}	14.056 (2.9400)***	110.290 (10.352)***	22.828 (5.5312)***	102.46 (9.7182)***
θ_{1i}	1.8636 (14.1540)***	0.8643 (10.7460)***	1.4495 (25.1050)***	1.0858 (23.0770)***
θ_{2i}	0.1155×10^{-9} (3.4875)***	-0.3339×10^{-9} (-3.3721)		
R^2	0.64	0.60	0.63	0.59
F	330.781	279.468	630.280	532.556

input use estimations as laid out in equations (49) through (52) of Chapter IV. The estimated coefficients are presented in Tables 30 and 31 for rainy (dry) season data. We analyze the input-use equations implied by Cobb-Douglas and Heteroskedastic models. In each of the models, two variates are considered, that is, risk-responsive case and risk-neutral case, where risk-neutral is risk-responsive variate with risk coefficient equals zero. Only two major inputs are considered because the same interpretation could be applied to other inputs.

Most of the coefficients in the input-use equations are statistically significant. Also, almost in all cases, the coefficients of θ_{1i} are statistically different from 1 as implied by the models. Furthermore, the coefficient of θ_{2i} are also statistically significantly different from zero excluding that of nitrogen demand on risk-responsive Heteroskedastic model. Recalling from equations (49) through (52) in Chapter IV, by the implication assuming that the models are ture, this coefficient measures the risk aversion parameter for particular input. We found that the coefficient ranges from 0.62×10^{-12} to 0.21×10^{-6} for nitrogen fertilizer and from -0.17×10^{-5} to 0.30×10^{-10} for human labor on rainy season data and for dry season data, the respective range is from 0.12×10^{-9} to 0.80×10^{-7} for nitrogen and from -0.14×10^{-6} to -0.33×10^{-9} for human labor. Hence, as far as nitrogen fertilizer is concerned, the farmers are risk-averter (the coefficient is positive). This is probably one of the reasons why some farmers did not apply some new inputs as recommended by extension personnel. This, in turn, will contribute to the widening yield gap between experimental stations and farmers' plots. However, the results from this analysis have to be taken with caution. Three notes must be in order: (1) the implicit assumption that the amount of input use is solely a function of two "aggregate" variables may not be realistic, (2) the clear departure from the assumption that $\theta_{0i} = 0$ and $\theta_{1i} = 1$ that must be imposed as in equation (51) of Chapter IV, and (3) the possibility of conflicting interpretation of the risk aversion coefficients derived for each input. Hence, these input-use equations have to be interpreted carefully.

In terms of human labor input, the signs of the coefficients are in the range of negative to positive for rainy season data and always negative for dry season data. Therefore, it would be safe to conclude that risk coefficient for human labor is indetermined, but it appears to be in the negative direction. It then suggests that farmers are also risk-averter toward labor.

To close this section, we summarize the main results of the analysis. We perform three alternative production specifications of estimating mean production function and implication of the estimation on the variance of production. The specifications are Cobb-Douglas, Crude model, and Heteroskedastic model. The mean production estimates of each model gives very different results. In spite of the possibility that they may result in the same positive marginal products of inputs as we expected, the implication of each model on the effect of input on the variability of output may be quite different.

Based on our Heteroskedastic model, the model that could separate the effect of inputs on mean production and variance of production, the elasticities of output with respect to inputs seed, nitrogen fertilizer, phosphorous fertilizer, human labor, animal labor, landholding, and insecticide or pesticide expense for rainy season data are 0.13, 0.00, 0.04, 0.09, 0.01, 0.74, and 0.01, respectively. Furthermore, by using Heteroskedastic model, in rainy season data, human labor and animal labor and insecticide or pesticide inputs behave as risk-reducing factors while other factors of production perform risk-inducing effects, such as seed, nitrogen fertilizer, phosphorous fertilizer, landholding, and insecticide or pesticide. In dry season data, all factors of production are shown to have risk-inducing effects.

The elasticities of variance of output with respect to inputs in rainy season data are 0.11, 0.03, 0.00, -0.28, -0.03, 1.88, and 0.07 for seed, nitrogen, phosphorous, human labor, animal labor, landholding, and insecticide expense, respectively. For dry season data, the respective elasticities are 0.81, 0.13, 0.05, 0.16, 0.37, 0.42, and 0.02. With the exception of landholding and insecticide inputs, the elasticities in dry season data are always higher in absolute values than in rainy season data. It appears that the existence of sufficient moisture during the cultivations in the rainy season helps to mitigate the variance of output caused by inputs.

Our risk aversion coefficients, given the estimates of production functions are true, are ranging from 0.62×10^{-12} to 0.21×10^{-6} for nitrogen fertilizer and from -0.14×10^{-6} to 0.30×10^{-10} for human labor. So, it is probably suggesting that the sample farmers are risk-averter on nitrogen fertilizer and on labor.

NOTES TO CHAPTER V

[1]The relationship between the change in probability and a change in one of the exogenous variables in probit model is derived as follows:

$$P = \text{Prob}(Y_i=1) = F(X\beta) = \int_{-\infty}^{X\beta} e^{-u^2/2} du$$

where $u \sim N(0,1)$, so

$$\frac{\delta P}{\delta X_k} = \beta_k f(X\beta)$$

so the elasticity is $(\delta P|P)/(\delta X_k|X_k) = \beta_k f(X\beta)\, X_k/P$ where $f(X\beta)$ is the value of the normal density function evaluated at point $X\beta$.

[2]The own-price (ε_{ii}) and cross-price elasticities (ε_{ij}) of demand are calculated through,

$$\varepsilon_{ii} = S_i - 1 + \frac{a_{ii}}{S_i}$$

$$\varepsilon_{ij} = S_j + \frac{a_{ij}}{S_j}$$

where S and a are share values of an input and a coefficient from the estimation.

[3]See Sumodiningrat (1982).

[4]Elasticities of substitution is derived from the relationship as follows:

a)own-elasticity of substitution

$$\sigma_{ii} = 1 - \frac{1}{S_i} + \frac{a_{ii}}{S_i S_j}$$

[5]Total elasticities of demand for variable inputs with respect to output and fixed inputs are not included.

[6]The Crude model is constructed from independent exponential function specifications for mean of production, $\bar{y}$, and for variance of production, Var(y), namely:

$$\ln \bar{y}_i = a_o + \Sigma\, a_k \ln\bar{X}_{ki} + v_i$$

$$\ln \text{Var}(y)_i = b_o + \Sigma\, b_k \ln\bar{X}_{ki} + w_i$$

where $\bar{X}$ is mean inputs, and $\bar{y}$ is mean output averaged in each observation over time. Var(y) for each farm was computed as the average over time of the squared deviations between output and the transformed (antiln) predictions of mean output.

[7]Initially, it was intended to apply Heteroskedastic error-component model as advanced by Anderson and Griffiths (1981) and Griffiths and Anderson (1982), but due to the inaccessibility to a flexible generalized nonlinear least squares software program, the original Just and Pope type is employed, namely:

$$y_i = f(X_i, \alpha) + g(X_i, \beta)u_i$$

where $E(u_i) = 0$, $\text{Var}(u_i) = 1$. One more important assumption that has to be imposed is $\text{Var}\{g(X_i, \beta)u_i\} = \sigma_i^2$, so ordinary nonlinear least squares is still valid. The estimation itself consisted of three steps:

STEP 1: A nonlinear regression of y_i on $f(X_i, \alpha)$ obtaining $\hat{\alpha}$.

STEP 2: An OLS regression of $\ln u_i{*}^2 = \ln \{y_i - f(X_i, \hat{\alpha})\}^2$ on $\ln X_i$ obtaining $\hat{\beta}$.

STEP 3: A nonlinear regression of $y_i{*} = y_i g^{-1/2}(X_i, \hat{\beta})$ on $f{*}(X_i, \hat{\alpha})$

$$= f(X_i, \hat{\alpha})g^{-1/2}(X_i, \hat{\beta}) \text{ obtaining } \tilde{\alpha}.$$

[8]i)For Cobb-Douglas function,

$$y = (\alpha_o \pi\, X_i^{\alpha_i})e^{u}$$

$$\text{Var}(y) = (\alpha_o \pi\, X_i^{\alpha_i})^2 \text{Var}(e^{u})$$

$$\frac{\delta \text{Var}(y)}{\delta X_i}\, \frac{X_i}{\text{Var}(y)} = 2\, \alpha_i (\text{the risk elasticity})$$

ii) For Heteroskedastic model,

$$y = \alpha_o \pi X_i^{\alpha_i} + \beta_o \pi X_i^{\beta_i} u$$

$$Var(y) = (\beta_o \pi X_i^{\beta_i})^2 Var(u)$$

$$\frac{\delta Var(y)}{\delta X_i} \frac{X_i}{Var(y)} = 2\beta_i \text{ (the risk elasticity).}$$

VI. SUMMARY, CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

This final chapter is comprised of three sections. The first section treats the overall approach and empirical results of the study. In the second section, a number of conclusions will be drawn from the empirical results summarized in the first section. The final section is devoted to the suggestion for further research along the lines followed in this study.

A. Summary

At the very beginning of this dissertation (Chapter I), we set out our theme as to try to gain some insights into the farm-level production decision making. For instance, a rice grower is aware of the potential increase in his yield if he adopts and applies new technological practices provided by experimental stations but he does not do so. Why?

In this study we follow two alternative paths that could narrow down the scope of the study through the identification and formulation of the problem. The first is to construct a model of seed selection adoption process through economic force dictated by the perceived potential cost or penalties that have to be borne by the farmers in his actual state of action, either by planting TVs or MVs (Chapter IV, Section A) in line with the induced-innovation hypothesis in part of farm producers. The second is to investigate whether the application of inputs bears some effect on production risk perceived by peasant farmers where risk is measured by the variance of output (Section B of Chapter IV).

In the first section of Chapter III, theoretical and empirical works on agricultural technological adoption is reviewed. The present stage of theoretical approaches in the area can be grouped as static or dynamic analyses. Meanwhile, based on the key explanatory factors affecting adoption of new technology, the empirical literature on the subject can be categorized through: (1) farm size, (2) risk and uncertainty, (3) human capital, (4) availability of information, (5) labor availability, (6) credit constraint, (7) tenure arrangement, (8) input supply constraint, and (9) aggregate adoption over time.

To the extent of the significance of risk and uncertainty in agriculture beyond the context of adoption of new technology, Section B of Chapter III provides an overall review. In the existing literature, there are three risk models being advanced as follows: (1) decision rules requiring no probability information, (2) safety-first rules, and (3) expected utility maximization rules. While in measuring risk attitudes empirically, literature can be classified into five groups, namely: (1) direct elicitation of utility function, (2) risk efficiency approach, (3) risk interval approach, (4) experimental methods, and (5) observed economic behavior.

Our empirical results (Chapter V) contains coefficient estimates of measured economic variables. The two-stage probit procedure is applied (Section A) on the seed selection model for the data set to accommodate the possibility of embodying seed selection as an endogenous decision variable. It is hypothesized to be a function of exactly the same exogenous variables that influence the total cost function. The estimated elasticities of probability of planting MVs with respect to seed price are -0.05 (1.26) during rainy (dry) season 1977 and 0.55 (0.51) during rainy (dry) season 1983. In passing, within the range of about five years between 1977 to 1983, there were more and more farmers applying new seed varieties in the sample farmers from 30.16 (35.79) percent of rainy (dry) season in 1977 to 55.08 (57.60) percent of rainy (dry) season in 1983.

In regard to nitrogen fertilizer prices, the elasticities are -2.11 (-0.08) for rainy (dry) season 1977 and -0.59 (-0.89) for rainy (dry) season 1983.

From the total cost function estimation, we found that almost all own-price elasticities of input demands have the appropriate signs on each data set for each farmer group (TV or MV) with the exception of the elasticities of demand of seed in MV group of dry season 1983 and of animal labor in TV group of rainy and dry season 1983. But cross-price elasticities of input demand have mixed signs. In one data set, they can be substitutes and in another they can be complements. However, there are some elasticities having signs unchanged in different data sets and farmer groups such as the cost-price elasticities of demand for seed with respect to nitrogen price and human labor wage, and the cross-price elasticities of demand for nitrogen fertilizer with respect to human labor wage, and finally the cross-price elasticities of demand for animal labor in regard to human labor wage being always positive. Also, the cross-price elasticities of demand for human labor with respect tc wage of animal labor are always negative (reflecting complementary).

The results of incorporating seed selectivity variable as derived from the two-stage probit procedure demonstrate that eight out of twelve total input share equations for TV and MV group of 1977 and 1983 data have statistically significant selectivity variable as seen on all seed share equation, on nitrogen share equations of MV of 1977 and 1983 data, and on human labor share of 1977 data. This is obviously evidence of the existence of selection bias in estimating those input share equations from respective subsample of farmers. On the other hand, for nitrogen share equations of TVs of 1977 and 1983 data, and human labor share equations of TV 1977 and of 1983 data, seed selection bias appears to be statistically insignificant.

With this selection bias in mind, we compare the total own-price elasticities of demand for input under the existence and the absence of selection bias. Total own-price elasticities of demand for seed with seed selectivity bias adjustment are -0.28 (-1.07) for rainy (dry) season 1977 and -0.18 (-0.07) for rainy (dry) season 1983. In the case of the absence of seed selectivity bias adjustment, the elasticities are -0.28 (-1.02) for rainy (dry) season 1977 and -0.24 (-0.16) for rainy (dry) season 1983. Total elasticities of demand for nitrogen fertilizer are -0.70 (-0.47) for rainy (dry) season 1977 and -0.29 (-0.42) for rainy (dry) season 1983 under selectivity bias adjustment, and in the absence of bias adjustment the elasticities are -0.77 (-0.47) for rainy (dry) season 1977 and -0.19 (-0.31) for rainy (dry) season 1983. In regard to human labor demand, the total elasticities are -0.22 (-0.11) for rainy (dry) season 1977 and -0.01 (-0.04) for rainy (dry) season

1983 under selectivity bias adjustment regime, and under no selectivity bias adjustment, the elasticities are -0.21 (-0.21) in rainy (dry) season 1977 and -0.04 (-0.05) in rainy (dry) season 1983. Moreover, in regard to animal labor, the total elasticities under bias adjustment regime are -1.87 (-1.16) rainy (dry) season 1977 and 0.48 (0.03) in rainy (dry) season 1983. Under no bias adjustment, the respective total own-price elasticities are -1.15 (-1.02) in rainy (dry) season 1977 and 0.41 (0.01) in rainy (dry) season 1983. Lastly, it appears that total own-price elasticities of demand show a tendency to wane over time based on the two samples.

Turning to production under risk analysis, on our Heteroskedastic model we found that for rainy season data, all estimates of mean production function are statistically (asymptotically) significant with the exception of nitrogen fertilizer coefficient, and in dry season data all coefficients except insecticide are statistically significant. The mean production elasticities are 0.13, 0.00, 0.04, 0.09, 0.01. 0.74, and 0.01 for rainy season data with respect to factors of production seed, nitrogen fertilizer, phosphorous fertilizer, human labor, animal labor, landholding and insecticide. In dry season data, the respective elasticities are 0.11, 0.03, 0.03, 0.13, 0.03, 0.68, and -0.01. Furthermore, from the variance of production estimation, we found that 4 (6) out of 8 (8) coefficients are statistically significant in rainy (dry) season data. Amount of labor, from human or animal, has the correct negative signs, but insecticide does not, as shown in rainy season data. Other factors of production have positive sign indicating risk-inducing characteristics such as seed, nitrogen, and phosphorous fertilizer, and landholding. With respect to dry season data, all coefficients show positive signs reflecting as risk-inducing factors including amount of labor, human and animal, and insecticide contrary to the expectation. In terms of the elasticities, the estimated elasticities of output variability with respect to factors of production implied by Heteroskedastic model are 0.11, 0.03, 0.00, -0.28, -0.03, 1.88 and 0.07 of seed, nitrogen and phosphorous fertilizer, human labor, landholding, and insecticide for rainy season data. In dry season data, the respective elasticities are 0.81, 0.13, 0.05, 0.16, 0.37, 0.42, and 0.02. In addition, our risk aversion coefficients, given the estimates of production function are true, are ranging from -0.62×10^{-12} to -0.21×10^{-6} for nitrogen fertilizer and from -0.14×10^{-6} to 0.30×10^{-10} for human labor. So, it is probably suggesting that the sample farmers are risk-averter toward nitrogen fertilizer input and human labor input.

B. Conclusions

The elasticities of the probability of selecting MVs and of input demands with respect to exogenous variables are not stable by comparing the two-year data sets. With respect to seed price, the probabilities of selecting MVs are increased with increases in the seed prices except for rainy season 1977. Meanwhile, the probabilities of selecting MVs are decreased with increases in nitrogen fertilizer prices. It appears on one hand that even though seed prices are increased, more farmers are using MVs probably due to the learning process over time. On the other hand, when nitrogen fertilizer prices increase, less farmers are willing to grow MVs. In regard to animal labor wage, the elasticities are positive indicating that an increase in animal wage tends to increase the probabilities of choosing MVs. For human labor wage of rainy season data, the same conclusion is true that it appears an increase in human labor wage tends to increase the probability of choosing MVs. For output level, the opposite is true in all data sets, that is, an increase in level of output results in a decrease in the probability of choosing MVs. The inclusion of seed selectivity bias adjustment has no a priori direction impact on existing forces at focus. It can be either reinforcing as lessening the total effect in question. Therefore, ignoring its existence through use of subsample of farmers may result in serious selection bias. This has been demonstrated by 8 out of 12 total input share equations that have statistically significant selectivity variables.

Total own-price elasticities of input demand are by and large inelastic with exception of elasticities of seed in dry season 1977 and animal labor in rainy and dry seasons 1977. Other than total own-price elasticities of demand for animal labor, we found that most total own-price elasticities are becoming smaller by contrasting 1977 to 1983 results at the same season.

From the Heteroskedastic model, we found that the most significant elasticity of production is of landholding. In rainy season data, the elasticity of production of nitrogen fertilizer is not significant, and in dry season data, the elasticity of production of insecticide or pesticide is negative although it is insignificant.

In regard to variance of production, the Heteroskedastic model concludes that in the rainy season data seed, nitrogen and phosphorous fertilizer, landholding, and insecticide inputs are risk-creating factors and labor (human and animal) inputs are risk-reducing factors. However, in the dry season all factors of production are shown to be risk-inducing factors. Furthermore, we found that with respect to nitrogen fertilizer and human labor inputs, farmers are risk-averter. This may be one of the factors that will cause the yield gap between experimental station and farmers' plot.

The results of the estimations in this research may not be of direct use by farmers, but they certainly could provide the basis not only for guidance in general policy formulation, but more specifically for indicating the direction and magnitude by which relevant instrumental variables need to be manipulated or introduced to achieve some desired objectives. In addition, they could also furnish reasonable information as to how peasant farmers might respond to agricultural development programs such as continued development of better new varieties. The qualitative and quantitative information of this type might be valuable to policy makers and extension personnel. Without a better understanding of farmer structure, price response, and economic motivation and production behavior, the planners and policy makers cannot fully appraise the potential of agricultural programs on production, farm income, and farmer welfare. Neither can the establishment of agro-industries and the expansion of industrial production of new factors of production be effectively evaluated. This becomes relevant upon considering the Government of Indonesia's efforts on the dissemination of better new rice varieties and the construction of fertilizer plants to meet the domestic demand in recent years.

C. Implications for Further Research

The empirical results of this study should be interpreted with some caution considering the following limitations. One is the meagerness and the quality of data. The second is the simplification and implicit restrictions entailed in the models. For example, in cost function estimation, we have to assume that prices are exogenous and somehow can be observed from input markets and everybody paying the same price. But in the real world, at least in the study area, the markets are not well established and the opportunity cost are not easy to evaluate. Some farmers might obtain their fertilizer from the provision of the government and their labor through specific customary arrangement. In addition, the model does not include farmer characteristics such as education, number of family members, financial strength, level of credit, tenure arrangement, irrigation, and aggregate adoption over time.

In production under risk case, data on agroclimatological characteristics such as soil type, soil fertility, precipitation, and temperatures, to name a few, are not available and hence not included. Unquestionably, this information should be considered in further research. Therefore, this should encourage future studies to consider those explanatory variables.

Not only by considering the addition of some explanatory variables mentioned above, further research could also hypothesize different models. In seed selection, for example, along the lines of the induced-innovation hypothesis we could extend that the seed selection criteria are governed by perceived utility associated with different choices. It also would be interesting to see the relationship of this seed selection variable with farmer characteristics. Others might consider the possibility of applying multiple categorical decision variables.

In production under risk case, as more data become available, we could construct a model of combining cross-section and time-series of an individual farmer. Also, we could consider relaxing the assumption that only yield is random, that is, we could assume that prices are also random. Of course, these suggestions might entail some costs in terms of time and money, but it may be worth a challenge.

REFERENCES CITED

Afiff, S., W. P. Falcon, and C. P. Timmer. "Elements of a Food and Nutrition Policy in Indonesia." In The Indonesian Economy. Edited by G. F. Papanek. New York: Praeger, 1980.

Anden-Lacsina, T. and R. Barker. "The Adoption of Modern Varieties." In Interpretative Analysis of Selected Papers from Changes in Rice Farming in Selected Areas of Asia. Los Banos, Philippines: International Rice Research Institute (IRRI), 1978.

Anderson, J. R. "Sparse Data, Climatic Variability, and Yield Uncertainty in Response Analysis." American Journal of Agricultural Economics 55(1):77-83, 1973.

Anderson, J. R. "Perspective on Models of Uncertain Decisions." In Risk, Uncertainty and Agricultural Development. Edited by J. A. Roumasset, J.-M. Boussard, and I. Singh. Laguna, Philippines: Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) and Agricultural Development Council (ADC), 1979.

Anderson, J. R., J. L. Dillon, and J. B. Handaker. Agricultural Decision Analysis. Ames, Iowa: Iowa State University Press, 1977.

Anderson, J. R. and W. E. Griffiths. "Production Risk and Input Use: Pastoral Zone of Eastern Australia." Australian Journal of Agricultural Economics 25(2):149-159, 1981.

Anderson, J. R. and W. E. Griffiths. "Production Risk and Efficient Allocation of Resources." Australian Journal of Agricultural Economics 26(3):226-232, 1982.

Antle, J. M. "Theory and Measurement of Output Distribution". Working Paper No. 81-3:1-21. Department of Agricultural Economics, University of California. Davis, California, 1981.

Antle, J. M. "Testing the Stochastic Structure of Production: A Flexible Moment-Based Approach." Journal of Business and Economic Statistics, 1983.

Antle, J. M. and W. J. Goodger. "Measuring Stochastic Technology: The Case of Tulare Milk Production." American Journal of Agricultural Economics 66(3):342-350, 1984.

Arcia, G. J. "Risk, Institutional Change and Technology Adoption for Low Income Farmers: An Analysis of New Bean Alternatives for the Southern Huila Region of Colombia, South America." Ph.D. dissertation. University of Missouri, Columbia, Missouri, 1980.

Arrow, K. J. "The Role of Securities in the Optimal Allocation of Risk-Bearing." Review of Economic Studies 31(2):91-96, 1964.

Barker, R. "Adoption and Production Impact of New Rice Technology: The Yield Constraints Problem." In Farm-level Constraints to High Rice Yields in Asia: 1974-1977. Laguna, Philippines: IRRI, 1979.

Barry, P. J., ed. Risk Management in Agriculture. Ames, Iowa: Iowa State University Press, 1984.

Beal, G. M. and J. M. Bohlen. "The Diffusion Process." Iowa State Agricultural Experiment Station Special Report No. 18, 1957.

Beattie, B. R. and C. R. Taylor. The Economics of Production. New York: Wiley & Sons, 1985.

Behrman, J. R. Supply Response in Underdeveloped Agriculture. Amsterdam: North-Holland, 1968.

Bell, C. "The Acquisition of Agricultural Technology: Its Determinants and Effects." Journal of Development Studies 9(1):123-159, 1972.

Bernoulli, D. "Specimen Theoriae Novae de Mensura Sortis." Commentarii Academiae Scientiarum Imperialis Petropolitanae 5:175-192, 1738. Translated by L. Sommer as "Expositions of a New Theory on the Measurement of Risk." Econometrica 22(1): 23-36, 1954.

Bhalla, S. S. "Farm and Technical Change in Indian Agriculture." In Agrarian Structure and Productivity in Developing Countries. Baltimore, Maryland: Johns Hopkins University Press, 1979.

Binswanger, H. P. "The Economics of Tractors in South Asia: An Analytical Review." Agricultural Development Council and the International Crops Research Institute for the Semi-Arid Tropics, New York: ADC, 1978.

Binswanger, H. P. "Attitudes Toward Risk: Experimental Measurement in Rural India." American Journal of Agricultural Economics 62(3):395-407, 1980.

Binswanger, H. P. and D. A. Sillers. "Risk Aversion and Credit Constraints in Farmers' Decision-Making: A Reinterpretation." Journal of Development Studies 20(1):5-21, 1983.

Binswanger, H. P., J. Dayantha, T. Balaranaia, and D. A. Sillers. "The Impact of Risk Aversion in Agricultural Decisions in Semi-Arid India." Development Economics Department, Washington, D.C.: The World Bank, 1980.

Blair, R. G. and R. Lusky. "A Note on the Influence of Uncertainty on Estimating of Production Function Models." Journal of Econometrics 3(4):391-394, 1975.

Borch, K. Economics of Uncertainty. Princeton, New Jersey: Princeton University Press, 1968.

B.P.S. (Biro Pusat Statistik = Central Bureau of Statistics). "Indonesian Food Balance Sheet, 1968." Statistik Indonesia, Statistical Pocketbook of Indonesia, Jakarta, Indonesia, 1970 & 1971.

B.P.S. Population of Indonesia: Results of the Sub-Sample of 1980 Population Census. Jakarta, Indonesia: B.P.S., 1982.

Burke, R. V. "Green Revolution Technologies and Farm Class in Mexico." Economic Development and Cultural Change 28(1):135-154, 1979.

Chipman, J. S. "The Ordering of Portfolios in Terms of Mean and Variance." Review of Economic Studies 40(2):167-190, 1973.

Clawson, D. L. "Intravillage Wealth and Peasant Agricultural Innovation." Journal of Development Areas 12(3):323-326, 1978.

Dalrymple, D. G. Development and Spread of HYV of Wheat and Rice in LDCs. Foreign Agricultural Report No. 95. Washington, D.C.: USDA, 1978.

Dapice, D. O. "An Overview of the Indonesian Economy." In The Indonesian Economy. Edited by G. F. Papanek. New York: Praeger, 1980.

David, C. C. "Fertilizer Demand in the Asian Rice Economy." Food Research Institute Studies 15(1):109-124, 1976.

Day, R. H. "Probability Distributions of Field Crops." Journal of Farm Economics 47(3):713-741, 1965.

Departemen Pertanian (Department of Agriculture). Vademekum Bina Usaha Petani Tanaman Pangan (Summary Statistics on Food Farm Management). Jakarta, Indonesia: Departemen Pertanian, 1983.

Diewert, W. E. "Application of Duality Theory." In Frontiers of Quantitative Economics Volume II. Edited by M. D. Intrilligator and D. A. Kendrick. New York: North Holland, 1974.

Dillon, J. L. The Analysis at Response in Crop and Livestock Production, Second Edition. New York: Pergamon Press, 1977.

Dillon, J. L. "Bernoullian Decision Theory: Outline and Problems." In Risk, Uncertainty and Agricultural Development. Edited by J. A. Roumasset, J.-M. Boussard, and I. Singh. Laguna, Philippines: SEARCA and ADC, 1979.

Dillon, J. L. and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." American Journal of Agricultural Economics 60(3):425-435, 1978.

Dobbs, T. T. and P. Foster. "Incentives to Invest in New Agricultural Inputs in North India." Economic Development and Cultural Change 21(1):101-117, 1972.

Feder, G. "Farm Size, Risk Aversion and the Adoption of New Technology Under Uncertainty." Oxford Economic Papers 32(2):263-283, 1980.

Feder, G. and R. Slade. "Adoption of New Technology." American Journal of Agricultural Economics 66(3):312-320, 1984.

Feder, G., R. E. Just, and D. Zilberman. "Adoption of Agricultural Innovations in Developing Countries: A Survey." Economic Development of Cultural Change 33(2):256-298, 1985.

Fishburn, P. C. Decision and Value Theory. New York: Wiley and Sons, 1964.

Freund, R. J. "The Introduction of Risk Into a Programming Model." Econometrica 24(2):253-263, 1956.

Friedman, M. and L. J. Savage. "The Utility Analysis of Choices Involving Risk," Journal of Political Economy 56(4):279-304, 1948.

Friedman, M. and L. J. Savage. "The Expected-Utility Hypothesis and the Measurability of Utility." Journal of Political Economy 60(6):463-474, 1952.

Fuller, W. A. "Stochastic Fertilizer Production Functions for Continuous Corn." Journal of Farm Economics 47(1):105-119, 1965.

Gafsi, S. and T. Roe. "Adoption of Unlike High-Yielding Wheat Varieties in Tunisia." Economic Development and Cultural Change 28(1):119-134, 1979.

Gomez, K. A., R. W. Herdt, R. Barker, and S. K. DeDatta. "A Methodology for Identifying Constraints to High Rice Yields on Farmers' Fields." In Farm-Level Constraints to High Rice Yields in Asia: 1974-77. Laguna, Philippines: IRRI, 1979.

Griffiths, W. E. and J. R. Anderson. "Using Time-Series and Cross-Section Data to Estimate a Production Function with Positive and Negative Marginal Risks." Journal of the American Statistical Association 77(379):529-536, 1982.

Griliches, Z. "Hybride Corn: An Exploration in the Economics of Technological Change." Econometrica 25(4):501-522, 1957.

Grisley, W. "Effect of Risk and Risk Aversion on Farm Decision-Making: Farmers in Northern Thailand." Ph.D. dissertation. University of Illinois, Urbana-Champaign, Illinois, 1980.

Grisley, W. and E. D. Kellogg. "Farmers' Subjective Probabilities in Northern Thailand: An Elicitation Analysis." American Journal of Agricultural Economics 65(1):78-82, 1983.

Hadar, J. and W. R. Russell. "Rules for Ordering Uncertain Prospects." American Economic Review 59(1):25-34, 1969.

Hallam, J. A., R. E. Just, and R. D. Pope. "Positive Economic Analysis and Risk Considerations in Agricultural Production." In New Directions in Econometric Modeling and Forecasting in U.S. Agriculture. Edited by G. C. Rausser. New York: North-Holland, 1982.

Halter, A. N. and G. W. Dean. Decisions Under Uncertainty: With Research Applications. Cincinnati, Ohio: South-Western, 1971.

Halter, A. N. and R. Mason. "Utility Measurement for Those Who Need to Know." Western Journal of Agricultural Economics 3(2):99-109, 1978.

Hamal, K. B. and J. R. Anderson. "A Note on Decreasing Absolute Risk Aversion Among Farmers in Nepal." Australian Journal of Agricultural Economics 26(3):220-225, 1982.

Hammond, J. S. "Towards Simplifying the Analysis of Decisions Under Uncertainty Where Preference is Nonlinear." Ph.D. dissertation, Harvard University, Boston, Massachusetts, 1968.

Hanock, G. and H. Levy. "The Efficiency Analysis of Choices Involving Risk." Review of Economic Studies 36(3):335-346, 1969.

Harris, B. "Innovation Adoption in Indian Agriculture: The High-Yielding Variety Program." Modern Asian Studies 6(1):71-98, 1972.

Harvey, A. C. "Estimating Regression Models With Multiplicative Heteroscedasticity." Econometrica 44(3):461-465, 1976.

Hayami, Y. and V. W. Ruttan. Agricultural Development: An International Perspective. Revised and Expanded Edition. Baltimore, Maryland: Johns Hopkins University Press, 1985.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." American Journal of Agricultural Economics 53(1):53-62, 1971.

Heady, E. O. Economics of Agricultural Production and Resource Use. New York: Prentice-Hall, 1952.

Heckman, J. J. "The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models." Annals of Economic and Social Measurement 5(4):475-492, 1976.

Helleiner, G. K. 1975. "Smallholder Decision Making: Tropical African Evidence." In Agriculture in Development Theory. Edited by L. G. Reynolds. New Haven, Connecticut: Yale University Press.

Herath, H. M. G., J. B. Handaker, and J. R. Anderson. "Choice of Varieties by Sri Lanka Rice Farmers: Comparing Alternative Decision Models." American Journal of Agricultural Economics 64(1):87-93, 1982.

Herdt, R. W. and C. Capule. Adoption, Spread, Production Impact of Modern Rice Varieties in Asia. Los Banos, Philippines: IRRI, 1983.

Herdt, R. W. and T. Wickham. "Exploring the Gap Between Potential and Actual Rice Yields in the Philippines." Food Research Institute Studies 14(2):163-181, 1975.

Hey, J. D. Uncertainty in Microeconomics. New York: New York University Press, 1979.

Hicks, W. H. and S. R. Johnson. "Population Growth and the Adoption of New Technology in Taiwanese Agriculture." Working Paper in Economics No. 1974-EG. Columbia, Missouri: University of Missouri, 1974.

Hiebert, D. "Risk, Learning, and the Adoption at Fertilizer Responsive Seed Varieties." American Journal of Agricultural Economics 56(4):764-768, 1974.

Huffman, W. E. "Allocative Efficiency: The Role of Human Capital." Quarterly Journal of Economics 91(1):59-80, 1977.

Jamison, D. T. and L. J. Lau. Farmer Education and Farm Efficiency. Baltimore, Maryland: Johns Hopkins University Press, 1982.

Jarvis, L. S. "Predicting the Diffusion of Improved Pasture in Uruguay." American Journal of Agricultural Economics 63(3):495-502, 1981.

Jensen, H. R. "Farm Management and Production Economics, 1946-70." In A Survey of Agricultural Economics Literature. Vol. 1. Edited by L. R. Martin. Minneapolis, Minnesota: University of Minnesota, 1977.

Johnson, E. G. Forward Prices for Agriculture. Chicago, Illinois: University of Chicago Press, 1947.

Jorgenson, D. W. and L. J. Lau. "The Duality of Technology and Economic Behavior." Review of Economic Studies 41(2):181-200, 1974.

Just, R. E. "An Investigation of the Importance of Risk in Farmers Decisions." American Journal of Agricultural Economics 56(1):14-25, 1974.

Just, R. E. and R. D. Pope. "Stochastic Specification of Production Functions and Economic Implications." Journal of Econometrics. 7(1):67-86, 1978.

Just, R. E. and R. D. Pope. "On the Relationship of Input Decision and Risk." In Risk, Uncertainty and Agricultural Development. Edited by J. A. Roumasset, J.-M. Boussard, and I. Singh. Laguna, Philippines: SEARCA and ADC, 1979a.

Just, R. E. and R. D. Pope. "Production Function Estimation and Related Risk Consideration." American Journal of Agricultural Economics 6(2):277-284, 1979b.

Just, R. E. and D. Zilberman. "Stochastic Structure, Farm Size, and Technology Adoption in Developing Agriculture." Oxford Economic Papers 35(2):307-328, 1983.

Kalirajan, D. "The Economic Efficiency of Farmers Growing High-Yielding, Irrigated Rice in India," American Journal of Agricultural Economics 63(3):566-570, 1981.

Kalirajan, K. and R. T. Shand. "Types of Education and Agricultural Productivity: A Quantitative Analysis of Tamil Nadu Rice Farming." Journal of Development Studies 21(2):232-243, 1985.

Kataoka, S. "A Stochastic Programming Model." Econometrica 31(1-2):181-396, 1963.

Khatikarn, K. "Risk and Uncertainty of Farmers in the Central Plain of Thailand." Ph.D. dissertation. University of Kentucky, Lexington, Kentucky, 1981.

King, R. P. and G. E. Oamek. "Risk Management by Colorado Dryland Wheat Farmers and the Elimination of the Disaster Assistance Program." American Journal of Agricultural Economics 65(2):247-255, 1983.

King, R. P. and L. J. Robison. "An Interval Approach to Measuring Decision Maker Preferences." American Journal of Agricultural Economics 63(3):510-520, 1981a.

King, R. P. and L. J. Robison. "Implementation of the Interval Approach to the Measurement of Decision Maker Preferences." Michigan State University Agricultural Experiment Station Research Report No. 418. Michigan State University, East Lansing, Michigan, 1981b.

Kislev, Y. and N. Shchari-Bachrach. "The Process of an Innovation Cycle." American Journal of Agricultural Economics 55(1):28-37, 1973.

Kramer, R. A. and R. D. Pope. "Participation in Farm Commodity Programs: A Stochastic Dominance Analysis." American Journal of Agricultural Economics 53(1):119-128, 1981.

Kunreuther, A. and G. Wright. "Safety-First, Gambling and the Subsistence Farmer." Decision Sciences Department Discussion, Paper No. 59. University of Pennsylvania, Philadelphia, Pennsylvania, 1974.

Kutcher, G. P. and P. L. Scandizzo. The Agricultural Economy of Northeast Brazil. Baltimore, Maryland: The World Bank, 1981.

Lee, L.-F. "Estimation of Limited Dependent Variable Models by Two-Stage Method." Ph.D. dissertation. The University of Rochester, Rochester, New York, 1976.

Lee, L.-F. G. S. Maddala, and R. P. Trost. "Asymptotic Covariance Matrices of Two-Stage Probit and Two-Stage Tobit Methods for Simultaneous Equations Models with Selectivity." Econometrica 48(2):491-503, 1980.

Lin, W. and H. Chang. "Specification of Bernoulli Utility Functions in Decision Analysis." Agricultural Economic Research 30(1):30-36, 1978.

Lindner, R. K. "Farm Size and the Time Lag to Adoption of a Scale Neutral Innovation." Mimeograph. University of Adelaide, Adelaide, Australia, 1980.

Lindner, R. K. and A. J. Fischer. "Risk Aversion, Information Quality, and the Innovation Adoption Time Lag." Mimeograph. University of Adelaide, Adelaide, Australia, 1981.

Lindner, R. K., A. J. Fischer, and P. Pardey. "The Time to Adoption." Economic Letters 2(2):187-190, 1979.

Lins, D., S. Gabriel, and S. Sonka. "An Analysis of the Risk Aversion of Farm Operators: An Asset Portfolio Approach." Western Journal of Agricultural Economics 6(1):15-30, 1981.

Lipton, M. "Agricultural Finance and Rural Credit in Poor Countries," World Development 4:321, 1976.

Lockheed, M. E., D. T. Jamison, and L. J. Lau. "Farmer Education and Farm Efficiency: A Survey." Economic Development and Cultural Change 29(1):37-75, 1980.

Lowdermilk, M. "Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab." Ph.D. dissertation. Cornell University, Ithaca, New York, 1972.

Luce, R. and H. Raiffa. Games and Decisions. New York: Wiley & Sons, 1957.

Magnusson, G. "Production Under Risk: A Theoretical Study." Acta Universitis Upsaliensis, Studia Oeconomica Upsaliensia 2:1-286, 1969.

Mangahas, M. "An Economic Analysis of the Diffusion of New Rice Varieties in Central Luzon." Ph.D. dissertation. University of Chicago, Chicago, Illinois, 1970.

Markowitz, H. M. "The Utility of Wealth." Journal of Political Economy 60(2):151-158, 1952.

Markowitz, H. M. Portfolio Selection: Efficient Diversification of Investments. New York: Cowles-Wiley, 1959.

Marschak, J. and W. H. Andrews. "Random Simultaneous Equation and the Theory of Production." Econometrica 12(3-4):143-205, 1944.

Martinez, J. C. "The Economics of Technological Change: The Case of Hybrid Corn In Argentina." Ph.D. dissertation. Iowa State University, Ames, Iowa, 1972.

Mears, L. A. The New Rice Economy of Indonesia. Yogyakarta, Indonesia: Gadjahmada University Press, 1981.

Mears, L. A. "Rice and Food Self-Sufficiency in Indonesia." Bulletin of Indonesian Economic Studies 10(2):122-138, 1984.

Mellor, J. W. "Production Economics and the Modernization of Traditional Agricultures." Australian Journal of Agricultural Economics 13(1):25-34, 1969.

Menezes, C. I. and D. L. Hanson. "On the Theory of Risk Aversion." International Economic Review 11(3):481-487, 1970.

Meyer, J. "Choice among Distributions." Journal of Economic Theory 14(2):326-336, 1977a.

Meyer, J. "Second Degree Stochastic Dominance with Respect to a Function." International Economic Review 18(2):477-487, 1977b.

Mohayidin, M. G. "Risk in Farm Decision-Making: A Case of Crop Selection in Two Malaysian Districts." Ph.D. dissertation, University of Hawaii, Manoa, Hawaii, 1981.

Moscardi, E. and A. de Janvry. "Attitudes Toward Risk Among Peasants." American Journal of Agricultural Economics 59(4):710-716, 1977.

Mubyarto. "Harga Beras dan Policy Produksi di Indonesia (Rice Price and Production Policy in Indonesia)," Agro Ekonomika 1(1):112-120, 1970.

Musser, W. N., H. P. Mapp, Jr., and P. J. Barry. "Applications I: Risk Programming," In Risk Management in Agriculture. Edited by P. J. Barry. Ames, Iowa: Iowa State University Press, 1984.

Nelson, R. R. and E. S. Phelps. "Investments in Humans, Technological Diffusion, and Economic Growth." American Economic Review 56:69-75, 1966.

Nikiphoroff, B. "Economic Analysis of Paraguayan Farms Under Uncertainty." Ph.D. dissertation. University of California, Davis, California, 1981.

Nordman, D. W. "Labor Inputs of Farmers: A Case Study of the Zaria Province of the North-Central State of Nigeria." Nigerian Journal of Economic and Social Studies 11(1):1-13, 1969.

O'Brien, D. T. "Risk and the Selection of Alternative Need Management Technologies in Philippine Upland Rice Production." Ph.D. dissertation. Oregon State University, Corvallis, Oregon, 1981.

O'Mara, G. T. "A Decision--Theoretic View of The Microeconomics of Technique Diffusion in a Developing Country." Ph.D. dissertation. Stanford University, Stanford, California, 1971.

O'Mara, G. T. The Microeconomics of Technique Adoption by Small-Holding Mexican Farmers. Development Research Center. Washington, D.C.: The World Bank, 1980.

Parthasarathy, G. and D. S. Prasad. Response to the Impact of the New Rice Technology by Farm Size and Tenure: Andhra Pradesh, India. Los Banos, Philippines: IRRI, 1978.

Pederson, G. D. "Selection of Risk-Preferred Rent Strategies: An Implication of Simulation and Stochastic Dominance." North Central Journal of Agricultural Economics 6(1):17-27, 1984.

Perrin, R. and D. Winkelmann. "Impediment to Technical Progress on Small Versus Large Farms." American Journal of Agricultural Economies 58(5):888-894, 1976.

Petzel, T. "Educations and the Dynamics of Supply." Ph.D. dissertation. University of Chicago, Chicago, Illinois, 1976.

Petzel, T. "The Role of Education in the Dynamics of Supply." American Journal of Agricultural Economics 60(3):445-451, 1978.

Pitt, M. M. "Farm-Level Fertilizer Demand in Java: A Meta-Production Function Approach." American Journal of Agricultural Economics 65(3):502-508, 1983.

Pope, R. D. and R. E. Just. "On the Competitive Firm under Production Uncertainty." Australian Journal of Agricultural Economics 21(2):111-118, 1977.

Pratt, J. W. "Risk Aversion in the Small and in the Large." Econometrica 32(1-2):122-136, 1964.

Pudasani, S. P. "The Effects of Education in Agriculture: Evidence From Nepal." American Journal of Agricultural Economics 65(3):509-515, 1983.

Pyle, D. H. and S. J. Turnovsky. "Safety First and Expected Utility Maximization in Mean Standard Deviation Portfolio Analysis." Review of Economics and Statistics 52(1):75-81, 1970.

Pyle, D. H. and S. J. Turnovsky. "Risk Aversion in Chance Constrained Portfolio Selection." Management Science 18(3):218-225, 1971.

Quirk, J. P. and R. Saposnik. "Admissibility and Measurable Utility Functions." Review of Economic Studies 29(2):140-146, 1962.

Ram, R. "Education as a Quasi-Factor of Production: The Case of India's Agriculture." Ph.D. dissertation. University of Chicago, Chicago, Illinois, 1976.

Ramsey, F. P. "Truth and Probability." 1926. In _The Foundation of Mathematics and Other Logical Essays_. Edited by R. B. Braithwaite. London: Kegan Paul, Trench, Trubner and Co., 1931.

Rasahan, C. A. "Government Intervention in Food Grain Markets: An Econometrics Study of the Indonesian Rice Economy." Ph.D. dissertation. University of Minnesota, St. Paul, Minnesota, 1983.

Robison, L. J., P. J. Barry, J. B. Kliebenstein, and G. F. Patrick. "Risk Attitudes: Concepts and Measurement Approaches." In _Risk Management in Agriculture_. Edited by P. J. Barry. Ames, Iowa: Iowa State University Press, 1984.

Robison, L. J. "An Appraisal of Expected Utility Hypothesis Tests." _American Journal of Agricultural Economics_ 64(2):367-375, 1982.

Rogers, E. _Diffusion of Innovation_. Iowa State Agricultural Experiment Station Special Report No. 18. Iowa State University, Ames, Iowa, 1957.

Rogers, E. _Diffusion of Innovations_. New York: Free Press of Glencoe, 1962.

Rosegrant, M. W. and J. A. Roumasset. "Stochastic Production Functions and Optimal Inputs." International Food Policy Research Institute, Washington, D.C., 1983. (Mimeographed.)

Rosenzweig, M. R. "Schooling, Allocative Ability, and the Green Revolution." Paper presented at the Meetings of the Eastern Economic Association, Washington, D.C., 1978.

Roumasset, J. A. _Rice and Risk: Decision Making Among Low-Income Farmers_. Amsterdam: North-Holland, 1976.

Roumasset, J. A., J.-M. Boussard, and I. Singh, eds. _Risk, Uncertainty and Agricultural Development_. Laguna, Philippines: SEARCA and ADC, 1979.

Roy, A. D. "Safety First and the Holding of Assets." _Econometrica_ 20(3):431-439, 1952.

Sanders, J. H. and A. D. de Hollanda. "Technology Design for Semiarid Northeast Brazil." In _Economics and the Design of Small-Farmer Technology_. Edited by A. Valdes, G. M. Scobie, and J. L. Dillon. Ames, Iowa: Iowa State University Press, 1979.

Sastrohoetomo, M. A. "Dampak Kebijaksanaan Harga Pupuk dan Beras Terhadap Pendapatan Masyarakat (Impact of Fertilizer and Rice Prices Policies on Society's Income)." Ph.D. dissertation. Institut Pertanian Bogor (Bogor Institute of Agriculture), Bogor, Indonesia, 1984.

Schluter, M. G. G. The Interaction of Credit and Uncertainty in Determining Resource Allocation and Income on Small Farms, Surat District, India. Occasional Paper No. 68, Employment and Income Distribution Project. Department of Agricultural Economics, Cornell University, Ithaca, New York, 1974.

Schultz, T. W. Production and Welfare of Agriculture. New York: Macmillan, 1949.

Schultz, T. W. Transforming Traditional Agriculture. New Haven, Connecticut: Yale University, 1964.

Schutjer, W. and M. van der Veen. Economic Constraints on Agricultural Technology Adoption in Developing Countries. Occasional Paper No. 5. Washington, D.C.: USAID, 1977.

Shackle, G. L. Expectations in Economics. 2nd ed. Cambridge: Cambridge University Press, 1952.

Shephard, R. W. The Theory of Cost and Production Functions. 2nd ed. Princeton, New Jersey: Princeton University Press, 1970.

Sidhu, S. "The Production Value of Education in Agricultural Development." Staff Paper No. P76-17. Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, Minnesota, 1976.

Silberberg, E. The Structure of Economics: A Mathematical Analysis. New York: McGraw-Hill, 1979.

Sillers, D. A. Measuring Risk Preferences of Rice Farmers in Nueva Ecija, Philippines: An Experimental Approach. New Haven, Connecticut: Yale University, 1980.

Simmons, R. L. and C. Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." American Journal of Agricultural Economics 57(3):472-479, 1975.

Singh, I. "Small Farmers and the Landless in South Asia." Staff Working Paper No. 320. Washington, D.C.: The World Bank, 1979.

Singh, C. and D. Zilberman. "Allocation of Fertilizer Among Crops under Risk—A Quadratic Programming Approach." Indian Journal of Agricultural Economics 39(1):77-83, 1984.

Srinivasan, T. N. "Farm Size and Productivity Implications of Choice Under Uncertainty." Sankhya: Indian Journal of Statistics 34, Series B, Part 4:416-419, 1972.

Stoneman, P. "Intra-Firm Diffusion, Bayesian Learning and Profitability." Economic Journal 91(362):375-388, 1981.

Sumodiningrat, G. "Varietal Choice and Input Demand in Rice Production in Indonesia." Ph.D. dissertation. University of Minnesota, St. Paul, Minnesota, 1982.

Teken, I. B. and H. Suwardi. "Food Supply and Demand and Food Policy." In Growth and Equity in Indonesia Agricultural Development. Edited by Mubyarto. Jakarta: Yayasan Agro Ekonomika, 1982.

Telser, L. "Safety-First and Hedging." Review of Economic Studies 23(1):1-16, 1955-1956.

Thomas, W. E., L. Blakeslee, L. Rogers, and N. Whittlesey. "Separable Programming for Considering Risk in Farm Planning." American Journal of Agricultural Economics 54(2):260-266, 1972.

Timmer, C. P. "The Political Economy of Rice in Asia: Indonesia." Food Research Institute Studies 14(3):197-231, 1975.

United Nations. Miscellaneous Issues of Yearbook of International Trade Statistics. Geneva: U.N.

Valdes, A. and D. L. Franklin. "Evaluation of Design Parameters for Cattle Production in the Colombian Llanos." In Economics and the Design of Small-Farmer Technology. Edited by A. Valdes, G. M. Scobie, and J. L. Dillon. Ames, Iowa: Iowa State University Press, 1979.

Valdes, A., G. M. Scobie, and J. L. Dillon, eds. Economics and the Design of Small-Farmer Technology. Ames, Iowa: Iowa State University Press, 1979.

van der Veen, M. "Analysis of Interfarm Variation in Rice Yields: An Economic Study of HYV Rice Production in Cavite Province, Philippines." Ph.D. dissertation. Pennsylvania State University, University Park, Pennsylvania, 1975.

von Neumann, J. and O. Morgenstern. Theory of Games and Economic Behavior. Princeton, New Jersey: Princeton University Press, 1947.

von Pischke, J. "When is Smallholder Credit Necessary?" Development Digest 16(3):6-14, 1978.

Walker, T. S. "Decision Making by Farmers and the National Agricultural Research Program on the Adoption and Development of Maize Varieties in El Salvador." Ph.D. dissertation. Stanford University, Stanford, California, 1980.

Weil, P. M. "The Introduction of the Ox Plow in Central Gambia." In African Food Production Systems: Cases and Theory. Edited by P. F. McLaughlin. Baltimore, Maryland: Johns Hopkins University Press, 1970.

Welch, F. "Education in Production." Journal of Political Economy 78(1):35-59, 1970.

Welch, F. "The Role of Investment in Human Capital Agriculture." In Distortion of Agricultural Incentives. Edited by T. W. Schultz. Bloomington, Indiana: Indiana University Press, 1978.

Widodo, S., Nasrullah, and H. Nataatmadja. "Rice and Indonesia's Agriculture." In Farm-level Constraints to High Rice Yields in Asia: 1974-1977. Laguna, Philippines: IRRI, 1979.

Wiens, T. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." American Journal of Agricultural Economics 58(4):629-635, 1976.

Wolgin, J. M. "Resource Allocation and Risk--A Case Study of Smallholder Agriculture in Kenya," American Journal of Agricultural Economics 57(4):622-630, 1975.

Wozniak, G. D. "The Adaptation of Interrelated Innovations: A Human Capital Approach." Review of Economics and Statistics 64(1):70-79, 1984.

Young, D. L. "Risk Concepts and Measures for Decision Analysis." In Risk Management in Agriculture. Edited by P. J. Barry. Ames, Iowa: Iowa State University Press, 1984.

Young, D. L., W. Lin, L. Robison, and R. Selley. "Risk Preferences of Agricultural Producers: Their Measurement and Use." In Risk Management in Agriculture: Behavioral, Managerial, and Policy Issues. Illinois Agricultural Experiment Station AE-4478. University of Illinois, Urbana-Champaign, Illinois, 1979.

Zacharias, T. P. and A. H. Grube. "An Economic Evaluation of Weed Control Methods Used in Combination with Crop Rotation: A Stochastic Dominance Approach." North Central Journal of Agricultural Economics 6(1):113-120, 1984.

Zeckhauser, R., and E. Keeler. "Another Type of Risk Aversion." Econometrica 38(5):661-665, 1970.

Zellner, A., J. Kmenta, and J. Dreze. "Specification and Estimation of Cobb-Douglas Production Function Models." Econometrica 34(4):784-795, 1966.

Zilberman, D. and R. E. Just. "Labor Supply Uncertainty and Technology Adoption." In _Seasonal Agricultural Labor Markets in the United States_. Edited by R. D. Emerson. Ames, Iowa: Iowa State University Press, 1984.

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IX. APPENDICES. TABLES

Table A1. Means of selected variables from farmers' sample used in the empirical estimation, rainy season

Variables	MV Farmers 1977	MV Farmers 1983	TV Farmers 1977	TV Farmers 1983
Seed quantity (kg)	27.32	26.87	11.89	13.92
Nitrogen fertilizer (kg)	118.99	152.84	63.97	99.47
Human labor (mandays)	23.66	67.33	26.76	41.47
Animal labor (animaldays)	420.04	415.44	254.14	349.24
Seed price (Rp/kg)	77.24	200.55	73.82	147.69
Nitrogen price (Rp/kg)	70.10	85.08	71.59	89.86
Human wage (Rp/hr)	69.58	87.42	70.94	92.72
Animal wage (Rp/hr)	61.49	162.59	60.86	144.07
Share of seed	0.06	0.06	0.05	0.04
Share of nitrogen	0.26	0.15	0.23	0.15
Share of human labor	0.66	0.73	0.61	0.75
Share of animal labor	0.02	0.06	0.11	0.06
Insecticide or pesticide expense (Rp)	543.53	2126.67	237.75	175.00
Landholding(ha)	0.63	0.58	0.31	0.36
Net paddy yield (kg)	956.34	2215.00	728.03	1211.49
Number of samples	92	141	213	115

Table A2. Means of selected variables from farmers' sample used in the empirical estimation, dry season

Variables	MV Farmers 1977	MV Farmers 1983	TV Farmers 1977	TV Farmers 1983
Seed quantity (kg)	15.57	17.85	11.02	12.96
Nitrogen fertilizer (kg)	83.64	105.84	54.25	93.24
Human labor (mandays)	23.85	48.78	19.21	36.31
Animal labor (animaldays)	215.89	239.69	189.52	293.06
Seed price (Rp/kg)	109.61	211.01	87.59	163.15
Nitrogen price (Rp/kg)	70.25	87.63	70.98	90.89
Human wage (Rp/hr)	70.23	89.42	73.19	94.56
Animal wage (Rp/hr)	59.51	164.08	64.88	149.90
Share of seed	0.09	0.07	0.10	0.04
Share of nitrogen	0.29	0.17	0.24	0.15
Share of human labor	0.60	0.72	0.63	0.77
Share of animal labor	0.02	0.04	0.03	0.04
Insecticide or pesticide expense (Rp)	388.04	1143.19	274.57	113.44
Landholding (ha)	0.39	0.46	0.28	0.33
Net paddy yield (kg)	684.33	1285.36	500.05	1181.08
Number of samples	97	144	174	106

Table A3. Estimated partial elasticities of substitution among variable inputs, 1977

Prices or wage rates of		Demand for Seed	Nitrogen	Human labor	Animal Labor
			Dry Season		
Seed	:TV	-15.48	4.42	-2.88	7.50
	MV	-4.89	-3.64	-4.50	5.54
Nitrogen	:TV	1.53	-2.29	0.34	0.30
	MV	0.58	-1.29	0.32	0.93
Human labor	:TV	0.91	0.90	-0.35	0.95
	MV	0.88	0.84	-0.34	0.94
Animal labor	:TV	62.93	-41.85	-17.99	-31.31
	MV	42.48	-6.50	-23.79	-42.97
			Rainy Season		
Seed	:TV	-3.79	0.38	-9.89	-1.32
	MV	-5.94	-8.46	1.05	1.0
Nitrogen	:TV	0.97	-3.68	-0.07	2.52
	MV	0.49	-2.51	0.70	0.70
Human labor	:TV	0.92	0.84	-0.22	0.83
	MV	1.00	0.95	-0.45	0.98
Animal labor	:TV	14.11	9.67	-47.36	-10.62
	MV	1.00	163.84	-37.47	-190.25

Table A4. Estimated partial elasticities of substitution among variable inputs, 1983

Price or wage rates of		Demand for Seed	Nitrogen	Human labor	Animal labor
Dry Season					
Seed	:TV	-19.22	9.16	-9.00	-11.12
	MV	2.79	2.98	-11.36	0.20
Nitrogen	:TV	1.67	-1.74	-1.65	-0.94
	MV	1.35	-2.09	-3.28	1.85
Human labor	:TV	0.97	0.90	-0.14	0.97
	MV	0.88	0.76	0.00	0.98
Animal labor	:TV	-0.72	-31.71	-11.70	20.79
	MV	-15.03	19.77	-9.43	-15.45
Rainy Season					
Seed	:TV	-20.14	14.98	-21.65	4.68
	MV	-0.11	4.53	-12.78	2.07
Nitrogen	:TV	1.44	-1.56	-4.62	1.44
	MV	1.63	-1.14	-3.29	0.05
Human labor	:TV	0.94	0.79	-0.04	0.98
	MV	0.89	0.81	-0.06	1.02
Animal labor	:TV	2.48	3.62	-1.79	20.27
	MV	-4.57	-4.44	-2.32	-2.72

Table A5. Simple correlation coefficients among factors of production in sample farmers

	Seed	Nitrogen fertilizer	Phosphorous fertilizer	Human labor	Animal labor	Landholding	Insecticide or pesticide expense
	Dry Season						
Seed	1.00	0.62***	0.33***	0.33***	0.04***	0.53***	0.11***
Nitrogen fertilizer		1.00	0.71**	0.63***	0.21***	0.84***	0.43***
Phosphorous fertilizer			1.00	0.52***	0.22***	0.64***	0.53***
Human labor				1.00	0.36***	0.69***	0.24***
Animal labor					1.00	0.22***	0.09**
Landholding						1.00	0.49***
Insecticide or pesticide expense							1.00
	Rainy Season						
Seed	1.00	0.74***	0.48***	0.73***	0.16***	0.90***	0.39***
Nitrogen fertilizer		1.00	0.69***	0.65***	0.25***	0.78***	0.52***
Phosphorous fertilizer			1.00	0.55***	0.43***	0.57***	0.51***
Human labor				1.00	0.27***	0.79***	0.29***
Animal labor					1.00	0.24***	0.12***
Landholding						1.00	0.42***
Insecticide or pesticide expense							1.00

**Significant at $\alpha_{0.05} = 1.960$.

***Significant at $\alpha_{0.01} = 2.576$.